6 Introduction – Design Guidelines

This chapter discusses recommended design guidelines for Greenville's bicycle system. Design recommendations are proposed for the bicycle facility types proposed in this Plan as well as others that may be contemplated in the future. Providing bicycle facilities on streets designed primarily for motor vehicle traffic can be challenging to implement, depending on the physical layout of the street. In some cases, bicycle facilities may be desirable on streets with higher vehicle speed and volumes. Placing bicycle facilities on these streets allows for a predictable environment for motorists and bicyclists by clarifying the appropriate position for each user on a roadway. Though opportunities to add bicycle facilities through roadway widening may exist in some locations, most major streets pose physical and other constraints requiring street retrofit measures within existing curb-to-curb widths. As a result, it may be necessary to reallocate existing street width through striping modifications to accommodate dedicated bicycle facilities.

Current AASHTO literature, research, and precedent examples support the notion of reducing 12' travel lanes to 10' lanes. The 2004 AASHTO Green Book states that travel lanes between 10 and 12 feet are adequate for urban collectors and urban arterials.[1] At the 2007 TRB Annual Meeting, a research paper using advanced statistical analysis supported the AASHTO Green Book in providing flexibility for use of lane widths narrower than 12 feet on urban and suburban arterials. "The research found no general indication that the use of lanes narrower than 12 feet on urban and suburban arterials increases crash frequencies. This finding suggests that geometric design policies should provide substantial flexibility for use of lane widths narrower than 12 feet." The research paper goes on to say "There are situations in which use of narrower lanes may provide benefits in traffic operations, pedestrian safety, and/or reduced interference with surrounding development, and may provide space for geometric features that enhance safety such as medians or turn lanes. The analysis results indicate narrow lanes can generally be used to obtain these benefits without compromising safety." and "Use of narrower lanes in appropriate locations can provide other benefits to users and the surrounding community including shorter pedestrian crossing distances and space for additional through lanes, auxiliary and turning lanes, bicycle lanes, buffer areas between travel lanes and sidewalks, and placement of roadside hardware."[2]

When the City of Greenville pursues lane narrowing as a means of implementing bike lanes, specific corridor analysis will be necessary. Changing the roadway design may also require a reduction in speed limit or other traffic calming measures. For roadways with higher speed limits and traffic volumes, wider bicycle lanes may be warranted. Further analysis of bicycle lane restriping projects is warranted to determine appropriateness of lane narrowing, bicycle lane widths, and speed limits that impact both motorists and bicyclists.

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[1] American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, Washington, DC 2004.

[2] Relationship of Lane Width to Safety for Urban and Suburban Arterials, Ingrid B. Potts, Harwood, D., Richard, K, TRB 2007 Annual Meeting

This chapter also discusses other important issues that will be considered as the City improves existing facilities and expands the bicycle network. This detailed summary of design standards includes bicycle facility design standards and policy recommendations from a variety of sources based on local standards and innovations, best practices and research from around the United States, including:

- City of Greenville Design And Specifications Manual
  www.greenvillesc.gov/publicworks/EngineeringDSM.aspx
- City of Greenville Trails and Greenways Master Plan design guidelines
  www.greenvillesc.gov/ParksRec/Trails/forms/GreenwaysMasterPlan/Chapter4.pdf
- South Carolina Department of Transportation, Engineering Directive Memorandum 22
  www.pccsc.net/pdfs/Engineering%20Directive%20Memorandum%2022.pdf
- 1999 AASHTO Guide for the Development of Bicycle Facilities (the basis for SCDOT design standards; the AASHTO guide is currently being updated and is expected to be released in 2011)
  www.sccrtc.org/bikes/AASHTO_1999_BikeBook.pdf
- National Association of City Transportation Officials (NACTO) Cities for Cycling Urban Bikeway Design Guide
  www.nacto.org/citiesforcycling.html
- National Park Service Rivers and Trails Program
  www.nps.gov/ncrc/programs/rtca/
- U.S. Forest Service Trail Development Guide
  www.fs.fed.us/database/acad/dev/trails/TRGenral.pdf
- Manual on Uniform Traffic Control Devices (2009)
  mutcd.fhwa.dot.gov/
- FHWA/FRA "Best Practices" for Planning and Designing Rails-with-Trails
  www.altaplanning.com/rails_with_trails_+_lessons+learned_+federal+rwt+study.aspx
- American with Disabilities Act – Trail and Sidewalk Publications
  www.access-board.gov/ada-aba/final.cfm
- Complete Streets and Context Sensitive Solutions (CSS)
  contextsensitivesolutions.org

This plan also recommends that the City continually reference and supplement the design guidance in this chapter with the latest bicycle facility guidelines and best practices, including the revised AASHTO guide (when published) and the NACTO Cities *Urban Bikeway Design Guide*. The NACTO guide represents the most up-to-date expertise in the field of bicycle facility design as implemented by leading agencies and municipalities throughout the United States. It is recommended that the NACTO guide serve as a prioritized reference for developing future bicycle facilities in Greenville.

6.1 Designing for Different Types of Cyclists

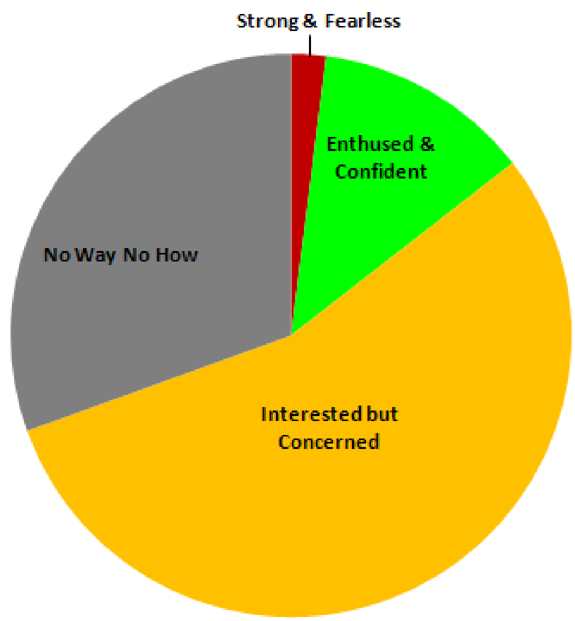
The skill level of the bicyclist also provides a dramatic variance on expected speeds and expected behavior. There are several systems of classification currently in use within the bicycle planning and engineering professions. These classifications can be helpful in understanding the characteristics and infrastructure preferences of different bicyclists. However, it should be noted that these classifications may change in type or proportion over time as infrastructure and culture evolve. Often times an instructional course can rapidly change a less confident bicyclist to one that can comfortably and safely share the roadway with vehicular traffic. Bicycle infrastructure should be planned and designed to accommodate as many user types as possible with separate or parallel facilities considered to provide a comfortable experience for the greatest number of bicyclists.

The following user types come from an excerpt from the 1999 AASHTO *Guide for the Development of Bicycle Facilities*:

> "*Although their physical dimensions may be relatively consistent, the skills, confidence and preferences of bicyclists vary dramatically. Some riders are confident riding anywhere they are legally allowed to operate and can negotiate busy and high speed roads that have few, if any, special accommodations for bicyclists. Most adult riders are less confident and prefer to use roadways with a more comfortable amount of operating space, perhaps with designated space for bicyclists, or shared-use paths that are away from motor vehicle traffic. Children may be confident riders and have excellent bike handling skills, but have yet to develop the traffic sense and experience of an everyday adult rider. All categories of rider require smooth riding surfaces with bicycle-compatible highway appurtenances, such as bicycle-safe drainage inlet grates.*
>
> *A 1994 report by the Federal Highway Administration used the following general categories of bicycle user types (A, B and C) to assist highway designers in determining the impact of different facility types and roadway conditions on bicyclists:*
>
> *Advanced or experienced riders are generally using their bicycles as they would a motor vehicle. They are riding for convenience and speed and want direct access to destinations with a minimum of detour or delay. They are typically comfortable riding with motor vehicle traffic; however, they need sufficient operating space on the traveled way or shoulder to eliminate the need for either themselves or a passing motor vehicle to shift position.*
>
> *Basic or less confident adult riders may also be using their bicycles for transportation purposes, e.g., to get to the store or to visit friends, but prefer to avoid roads with fast and busy motor vehicle traffic unless there is ample roadway width to allow easy overtaking by faster motor vehicles. Thus, basic riders are comfortable riding on neighborhood streets and shared-use paths and prefer designated facilities such as bike lanes or wide shoulder lanes on busier streets.*
>
> *Children, riding on their own or with their parents, may not travel as fast as their adult counterparts but still require access to key destinations in their community, such as schools, convenience stores and recreational facilities. Residential streets with low motor vehicle speeds, linked with shared-use paths and busier streets with well-defined pavement markings between bicycles and motor vehicles can accommodate children without encouraging them to ride in the travel lane of major arterials.*"

The AASHTO classifications above have been the standard for at least 15 years and have been found to be helpful when assessing existing bicyclists. However, these classifications have not been found to accurately describe all existing types of bicyclists, nor account for the population as a whole, including potential bicyclists who are interested in riding but may not feel existing facilities provide enough safety. Supported by data collected nationally after 2006, alternative categories have been developed to address the 'attitudes' of Americans towards bicycling.

Less than 2 percent of Americans comprise a group of bicyclists who are '**Strong and Fearless**'. These bicyclists typically ride anywhere on any roadway regardless of roadway conditions or weather. These bicyclists can ride faster than other user types, prefer direct routes and will typically choose roadway connections – even if shared with vehicles – over separate bicycle facilities such as bicycle paths. Another 10 to 13 percent fall under the category of '**Intermediate**' bicyclists who are confident and mostly comfortable riding on all types of bicycle facilities but will usually prefer low traffic streets or multi-use pathways when available. These bicyclists may deviate from a more direct route in favor of a preferred facility type. This group includes all kinds of bicyclists including commuters, recreationalists, racers, and utilitarian bicyclists.



The remainder of the American population does not currently ride a bicycle regularly. 50-60 percent of the population can be categorized as '**Interested but Concerned**' and represents bicyclists who typically only ride a bicycle on low traffic streets or bicycle paths under favorable conditions and weather. These infrequent or potential bicyclists perceive significant barriers towards increased use of bicycling with regards to traffic and safety.

These bicyclists may become more regular riders with encouragement, education and experience. The final 25-30 percent of Americans are not bicyclists, and perceive severe safety issues with riding in traffic. Some people in this group may eventually give bicycling a second look and may progress to one of the user types above. A significant portion of these people will never ride a bicycle under any circumstances.

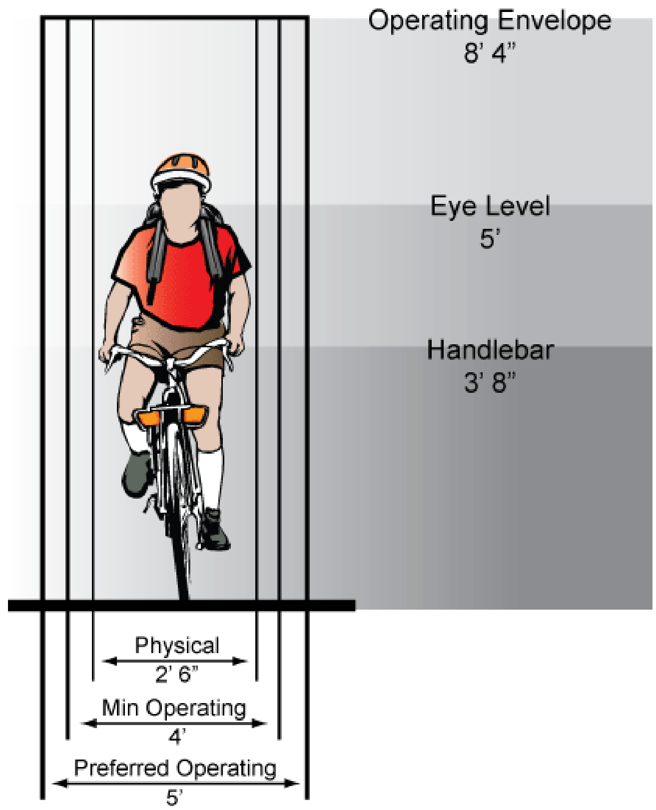
The purpose of this chapter is to provide the facility designer with an understanding of how bicyclists operate and how their bicycle influences that operation. Bicyclists, by nature, are much more sensitive to poor facility design, construction and maintenance than motor vehicle drivers because they are physically exposed to the elements and lack the protection provided by the vehicle's structure and numerous other safety features. By understanding the unique characteristics and needs of bicyclists, the facility designer can provide the highest quality facilities and minimize risk to the bicyclists using them.

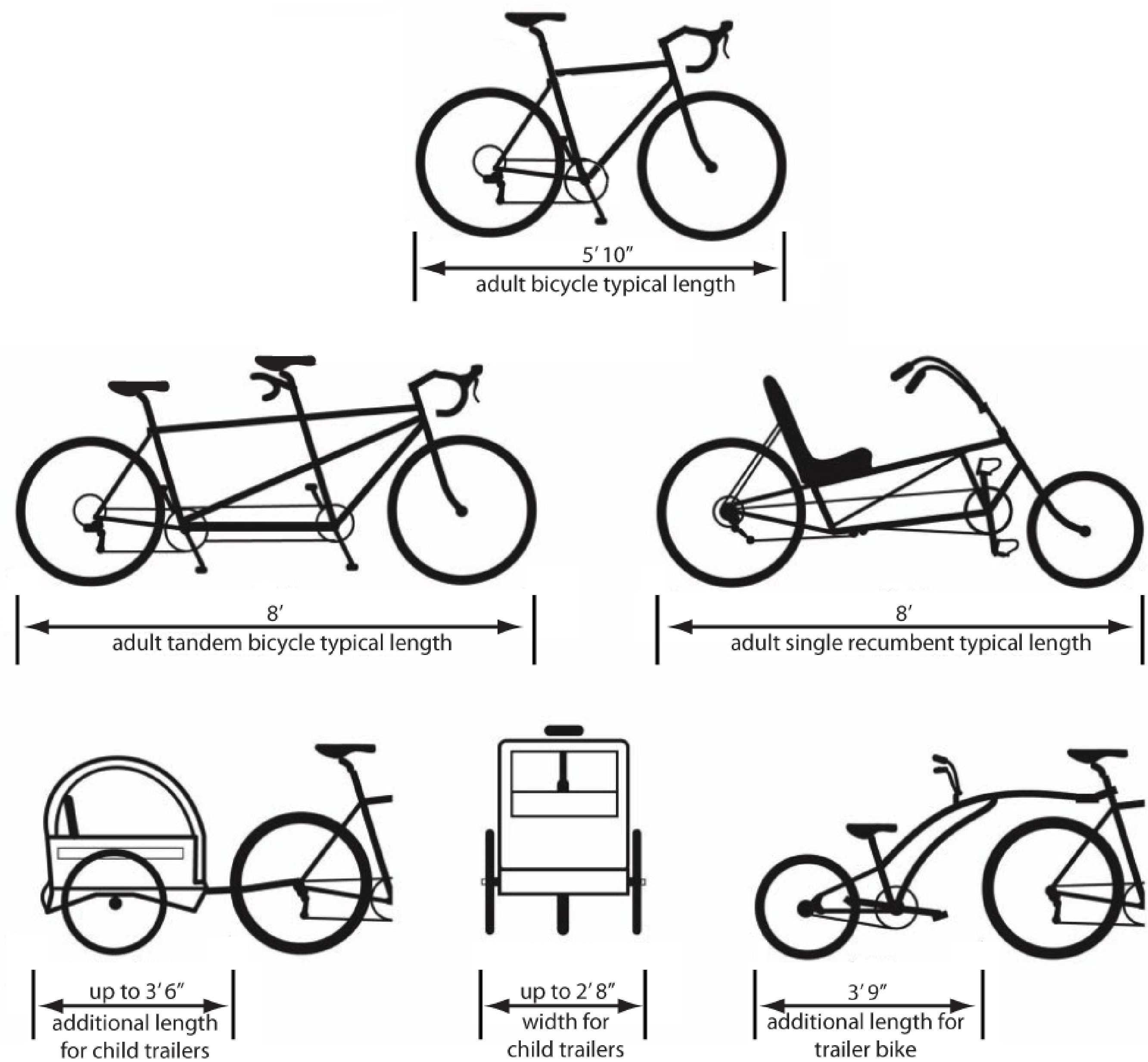
6.2 The Bicycle as a Design Consideration

Similar to motor vehicles, bicyclists and their bicycles come in a variety of sizes and configurations. This variation can take the form of the variety in types of vehicle (such as a conventional bicycle, a recumbent bicycle, or a tricycle), or the behavioral characteristics and comfort level of the bicyclist riding the vehicle. Any bikeway undergoing design should consider what types of bicycles can be expected on the facility and design with that set of critical dimensions in mind.

The operating space and physical dimensions of a typical adult bicyclist are shown below. Clear space is required for the bicyclist to be able to operate within a facility; this is why the minimum operating width is greater than the physical dimensions of the bicyclist. Although four feet is the minimum acceptable operating width, five feet or more is preferred. Other pertinent dimensions are included in the graphic above.

Outside of the design dimensions of a typical bicycle, there are many commonly used pedal driven cycles and accessories that should be considered when planning and designing bicycle facilities. The most common types including tandem bicycles, recumbent bicycles, and trailer accessories are depicted in the graphic on the following page.




5′ 10″
adult bicycle typical length
8′
adult tandem bicycle typical length
8′
adult single recumbent typical length
up to 3′ 6″
additional length
for child trailers
up to 2′ 8″
width for
child trailers
3′ 9″
additional length for
trailer bike

The table below summarizes the typical dimensions for most commonly encountered bicycle designs:

Bicycle as Design Vehicle – Typical Dimensions		
Bicycle Type	**Feature**	**Typical Dimensions**
Upright Adult Bicyclist	Physical width	2 ft 6 in
	Operating width (Minimum)	4 ft
	Operating width (Preferred)	5 ft
	Physical length	5 ft 10 in
	Physical height of handlebars	3 ft 8 in
	Operating height	8 ft 4 in
	Eye height	5 ft
	Vertical clearance to obstructions (tunnel height, lighting, etc).	10 ft
	Approximate center of gravity	2 ft 9 in to 3 ft 4 in
Recumbent Bicyclist	Physical length	8 ft
	Eye height	3 ft 10 in
Tandem Bicyclist	Physical length	8 ft
Bicyclist with child trailer	Physical length	10 ft
	Physical width	2 ft 6 in

The speed that various types of bicyclists can be expected to maintain under various conditions can also have influence over the design of facilities such as shared use paths. The following table provides typical bicyclist speeds for a variety of conditions.

Design Speed Expectations

Bicycle Type	Feature	Typical Speed
Upright Adult Bicyclist	Paved level surfacing	15 mph
	Crossing Intersections	10 mph
	Downhill	30 mph
	Uphill	5-12 mph
Recumbent Bicyclist	Paved level surfacing	18 mph

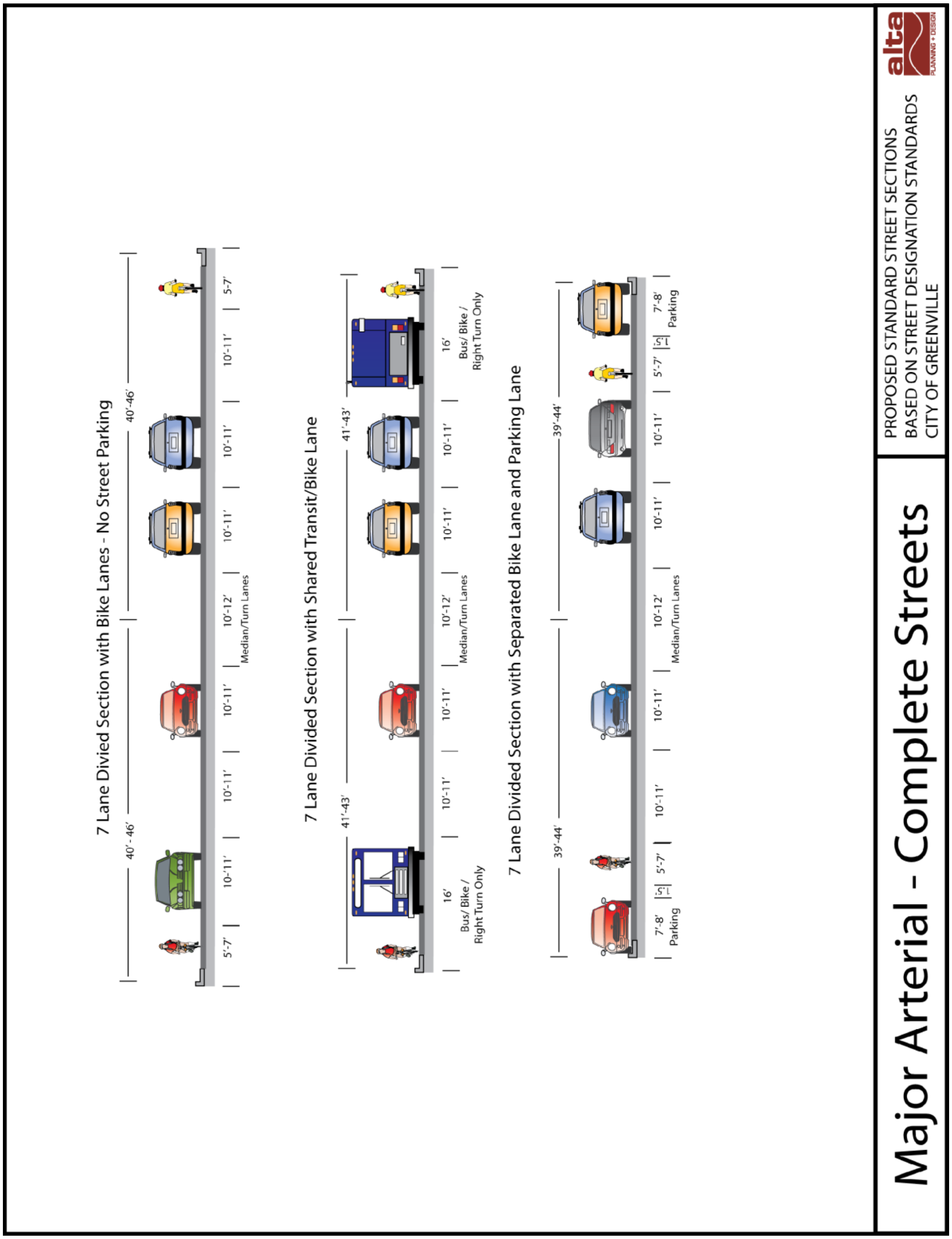
6.3 Routine Accommodation of Bicyclists (Complete Streets)

Bicyclists have legal access to all city streets and state roadways (with the exception of limited access freeways). While this Bicycle Plan identifies a specific subset of streets to be included in the Greenville bikeway network, many bicyclists will need to use streets outside of the network in order to reach their destinations. Therefore, it is important that all roadways be designed to accommodate bicyclists.

The following figures provide a series of potential roadway cross sections that include design provisions for bicyclists. These cross sections are not intended to be adopted standards. They are included in order to illustrate possible ways to reconfigure roadways for enhanced bicycle access. In many cases, it may be necessary to use the "absolute minimum" travel and turn lane widths in order to accommodate bicycle lanes. Whether or not "absolute minimum" lane widths are acceptable should be determined on a case-by-case basis (in consultation with SCDOT, where applicable) through sound engineering judgment including an analysis of various site-specific factors including length of roadway segment, traffic speeds, parking turnover, and bus and truck volumes.

THE CROSS SECTIONS ILLUSTRATED IN THE FOLLOWING PAGES ARE NOT INTENDED AS STANDARDS. THEY MERELY ILLUSTRATE SOME EXAMPLES OF HOW BICYCLE TRAFFIC CAN BE ACCOMMODATED WITHIN EXISTING, STANDARD-WIDTH CITY RIGHTS-OF-WAY.

Figure 6.1. Major Arterial - Complete Streets



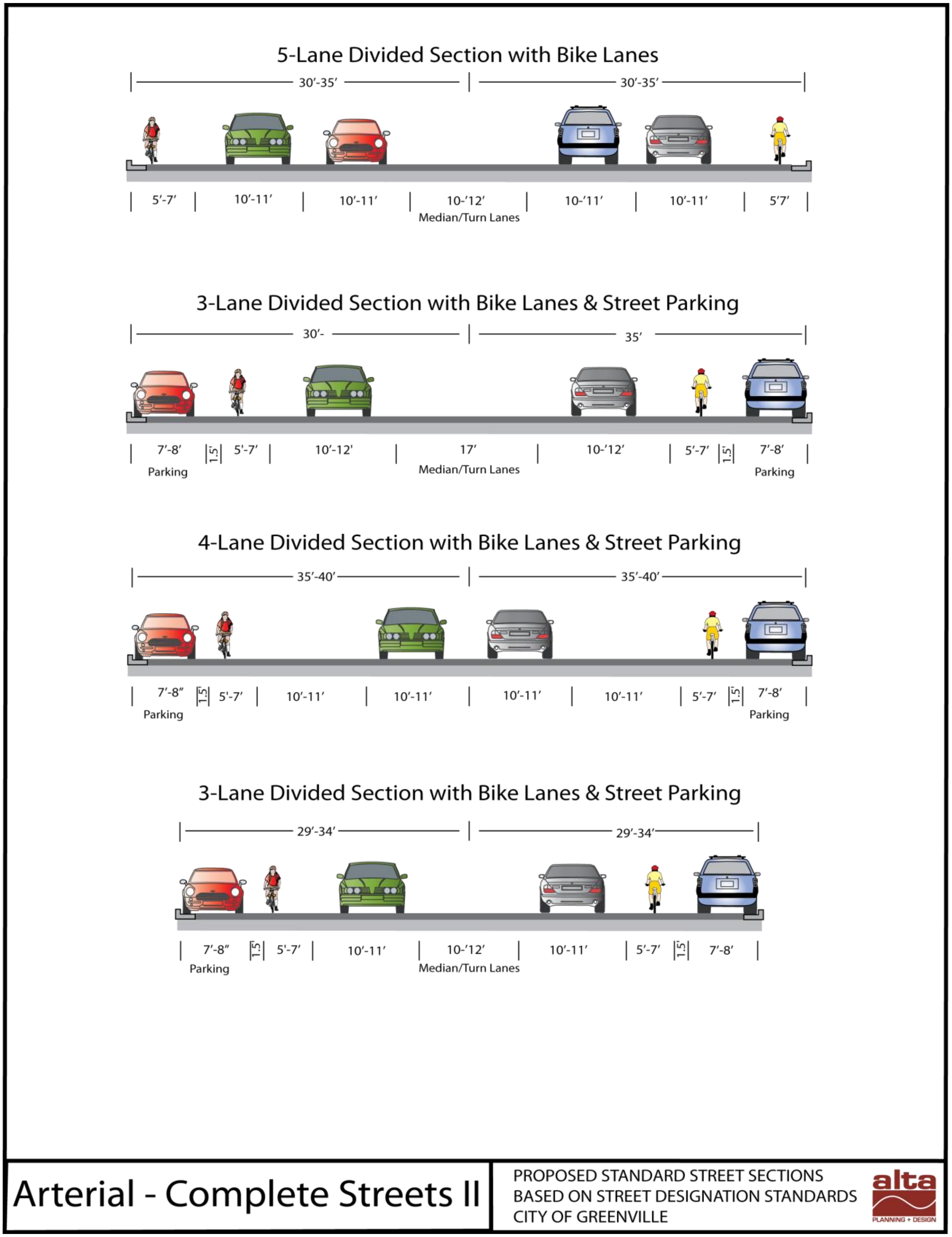
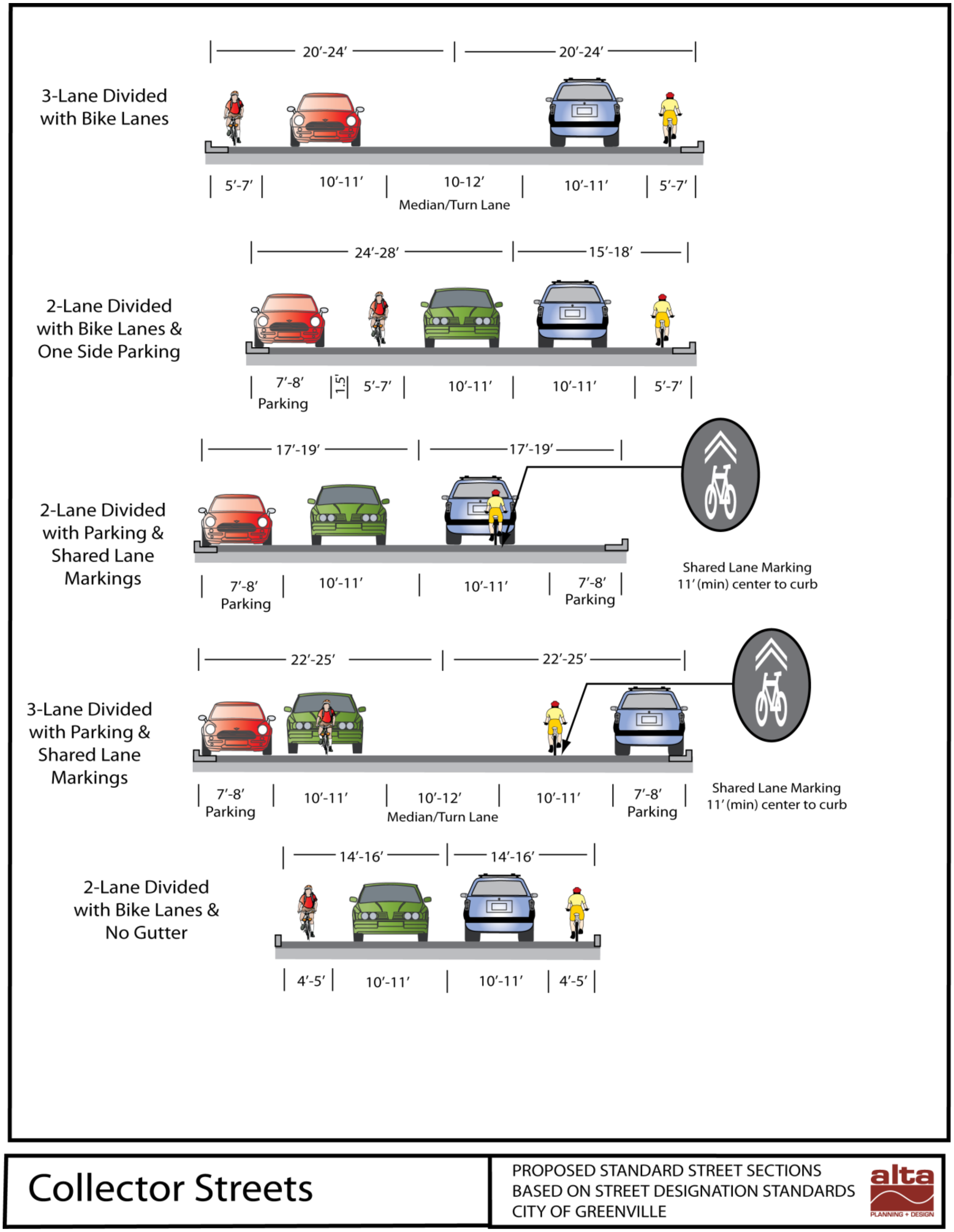


Figure 6.2. Arterial -- Complete Streets II

Figure 6.3. Collector Streets - Complete Streets



On-Street Facility Design Guidelines

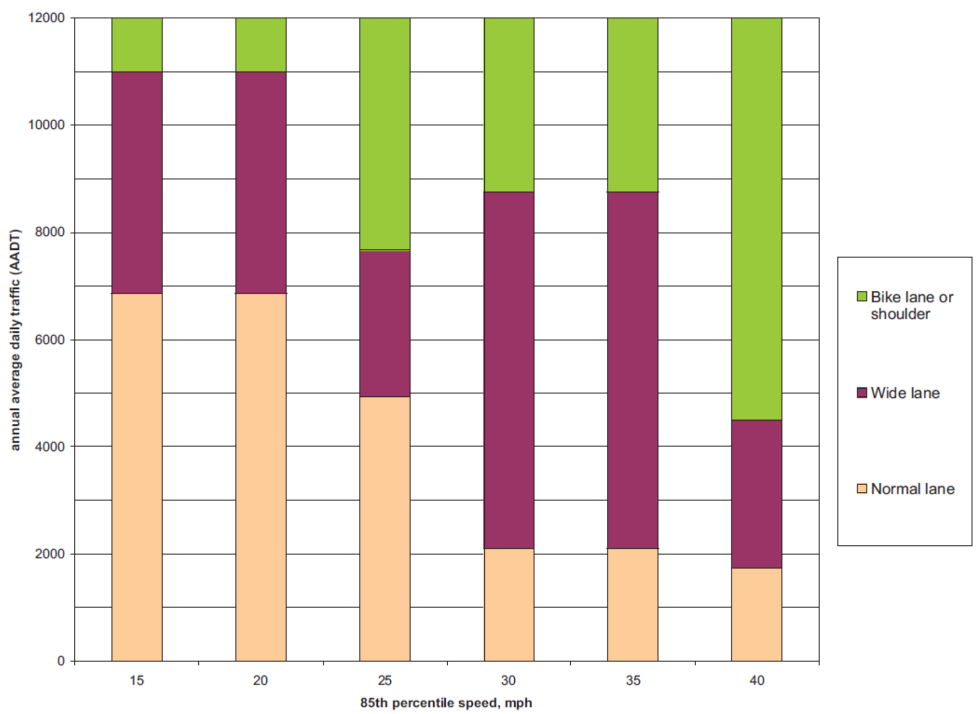
There are a range of different types of bicycle facilities that can be applied in various contexts, which provide varying levels of protection or separation from automobile traffic. This section summarizes best practice on-street bicycle facility design from North America and elsewhere.

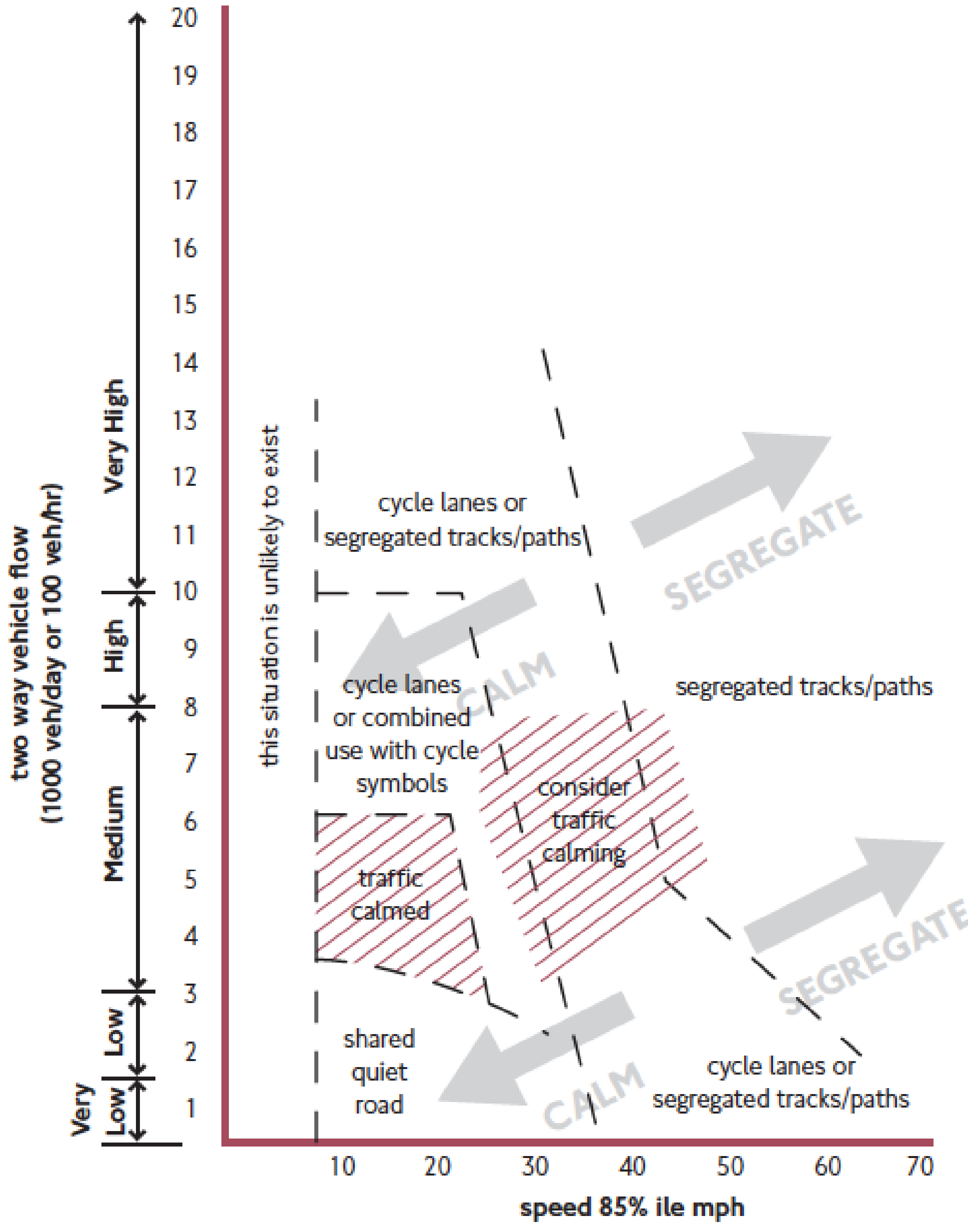
Facility Selection

There are a wide variety of techniques for selecting the type of facility for a given context. Roadway characteristics that are often used include: traffic volume, traffic speed, percent truck traffic, travel lane widths, presence of parking, and land use context.

There are no 'hard and fast' rules for determining the most appropriate type of facility for a particular location; engineering judgment and planning skills are critical elements of this decision. A 2002 study combined bikeway dimension standards for ten different communities in North America. The goal of the study was to survey the varying requirements available and provide a best practices approach for providing bicycle facilities. The study included a comparison with European standards, and found that "North Americans rely much more on wide vehicular lanes for bicycle accommodation than their counterparts overseas." The table below shows the results of this analysis, which recommends use of bike lanes or shoulders, wide lanes, or normal lanes. Finally, the study shows the 'worldwide speed-volume chart,' which synthesizes findings from Europe and North America. The final chart is useful for the inclusion of separated lanes, or cycle tracks, and generally has a lower threshold for increasing separation than the North America selection **(Figure 4)**.

Figure 4: North American Bicycle Facility Selection Chart
(King,. Michael. (2002). Bicycle Facility Selection: A Comparison of Approaches. Pedestrian and Bicycle Information Center and Highway Safety Research Center, University of North Carolina – Chapel Hill.)





Notes:

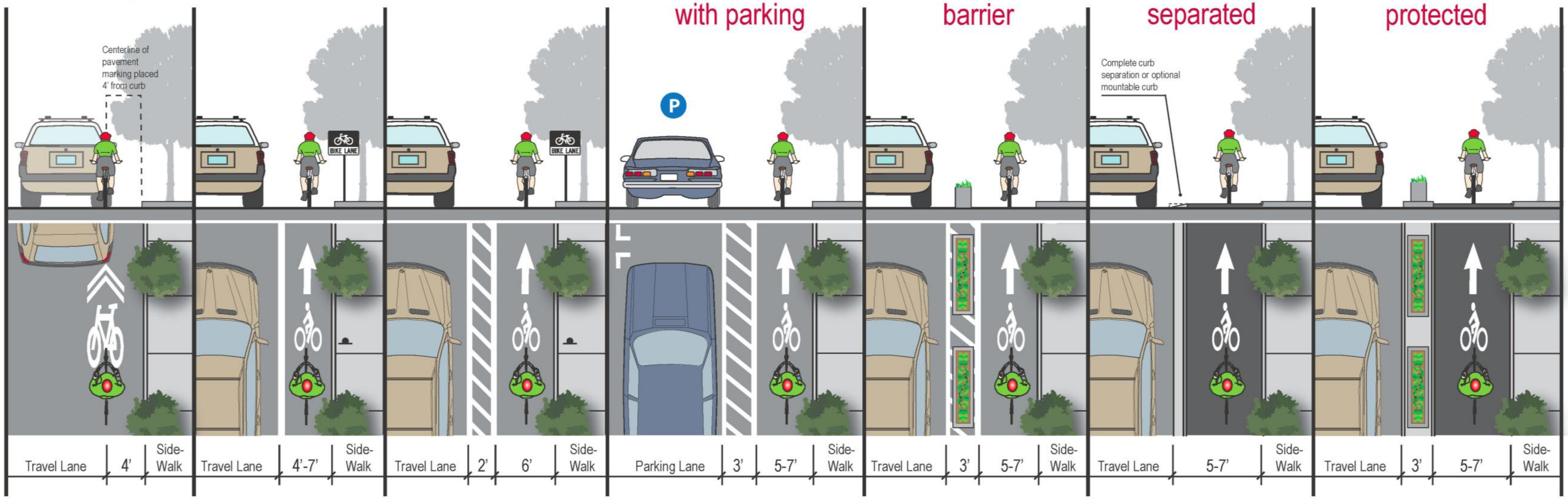
1. Each route will need to be judged in the light of its specific situation
2. Cycle lanes or tracks will not normally be required in traffic calmed areas
3. Congested traffic conditions may benefit from cycle lanes or tracks
4. Designs should tend to either calm traffic or segregate cyclists

Bicycle facility solutions are based on motor traffic volume and speed. **Figure 5** outlines the relationship between street conditions and the appropriate bicycle facility for that street. As traffic speeds increase, the bicycle facility should become more segregated to provide greater relief and separation from differing uses. As road volumes and speeds decrease, bicyclists can more safely operate within the same rights of way as motorists.

On-Street Bikeway Continuum

On-Street Marked Bikeway Continuum

least protected → most protected



Shared Lane Markings

- Positions bicyclists in the travel lane
- Alerts motorists to the presence of bicyclists
- Encourages bicyclists to ride an appropriate distance away from the "door zone" on streets with parking
- Should never be used as a replacement for bicycle lanes

Bike Lane

- Exclusive bicycle travel lane increases safety and promotes proper riding
- Reduces possibility that motorists will stray into bicyclists' path
- Visual reminder of bicyclists' right to the road
- 6' width recommended. 4' width in constrained locations
- Bike lanes wider than 7' may encourage vehicle loading in bike lane

Buffered Bike Lane

- Provides cushion of space to mitigate friction with motor vehicles on streets with frequent or fast motor vehicle traffic
- Allows bicyclists to pass one another or avoid obstacles without encroaching into the travel lane
- Increases motorist shy distance from bicyclists in the bike lane
- Requires additional roadway space and maintenance
- Reduces risk of 'dooring' compared to a bike lane

Cycle Track: at-grade, protected, with parking

- Dedicates and protects space for bicyclists and improves perceived comfort and safety
- Reduces risk of 'dooring' compared to a bike lane, and eliminates of the risk of a doored cyclist being run over by a motor vehicle
- Low implementation cost through use of existing pavement using parking lane as a barrier
- Use along roadways with high motor vehicle volumes and/or speeds
- Best on streets with parking lanes with a high occupancy rate

Cycle Track: protected with barrier

- Provides similar benefits as a cycle track with an on-street parking buffer
- Best used on roads with high speeds and long distances between intersections and driveways
- Innovative bicycle-friendly design needed at intersections to reduce conflicts between turning motorists and bicyclists
- Width should never be taken from the pedestrian zone to make room for a cycle track

Cycle Track: raised and curb separated

- Change in level clearly demarcates space for different users and reduces conflicts between bicyclists and pedestrians
- Where bicyclists may enter or leave the cycle track, or where motorists cross at a driveway, the curb should be mountable with a small 45 degree ramp, allowing cyclist turning movements

Cycle Track: raised and protected

- Cycle track should be two or three inches above street-level, and the sidewalk should be an additional two to three inches above cycle track
- Maintenance of the cycle track requires specialized sweepers
- Where opportunities exist, the buffer zone may be expanded to include bicycle parking

Shoulder Bikeways

Design Summary

Recommended widths (measured from painted edgeline to edge of pavement):

6' on roadways with posted speed limits of 40 mph or greater.

5' on roadways with posted speed limits of 35 mph or below.

4' may be considered on low-speed, low-volume streets where right-of-way constraints exist.

Can include pavement markings and 'Share the Road" signage.

See bike lane section (**p. 6-17**) for additional guidance for determining if bike lanes are required.

Discussion

On streets without adequate space for bike lanes, or on rural roads with a large shoulder, shoulder bikeways can accommodate bicycle travel. Shoulder bikeways are generally used by commuter and long-distance recreational riders, rather than families with children or more inexperienced riders.

In many cases, the opportunity to develop a full standard bike lane on a street where it is desirable may be many years. It is possible to stripe the shoulder in lieu of bike lanes if the area is 50 percent of the desirable bike lane width and the outside lane width can be reduced to the AASHTO minimum. If the available bike lane width is 2/3 of the desirable bike lane width, the full bike lane treatment of signs, legends, and a 4-6" bike lane line would be provided. Where feasible, extra width should be provided with pavement resurfacing jobs, but not exceeding desirable bike lane widths.

Guidance

See also: MUTCD Section 9B. 20 Bicycle Guide Signs.

Recommended shoulder bikeway configuration.

Shoulder bikeways are appropriate along roadways with no curb and gutter to provide space for cyclists, breakdown area for motorists, and to extend pavement life.

Shared Lane Markings - Sharrow

Design Summary

Minimum of 11 feet from edge of curb where on-street parking is present. If parking lane is wider than 7.5 feet the sharrow should be moved further out accordingly. The width of the door zone is generally assumed to be 2.5 feet from the edge of the parking lane.

Greenville has already applied the sharrow as an appropriate bicycle facility on several streets, including East North Street, West Park Avenue, and others. Additionally, Greenville has developed signage specific to roadways with sharrows.

If used on a street without on-street parking that has an outside travel lane that is less than 14 feet wide, the centers of the sharrow should be at least 4 feet from the edge of the pavement.

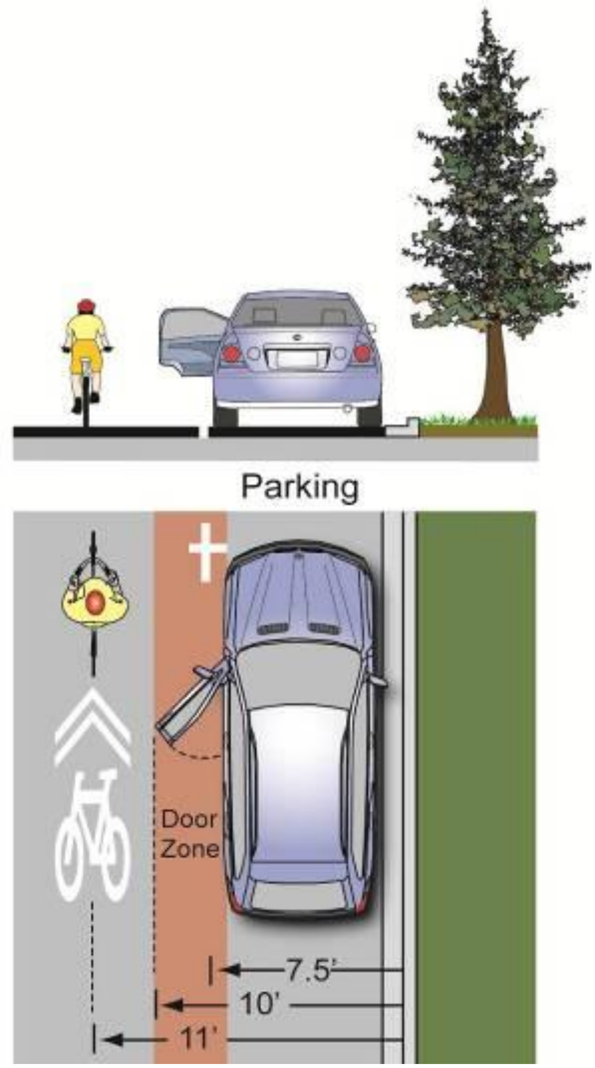
If used, the sharrow should be placed immediately after an intersection and spaced at intervals not greater than 250 feet thereafter and may be spaced closer together to achieve desired spatial definition.

The sharrow is not recommended on roadways with speeds above 35mph.

Discussion

Recently, Shared Lane Marking stencils (also called "Sharrows") have been accepted by the MUTCD (Manual on Uniform Traffic Control Devices) for use nationwide as an additional treatment for bike route facilities. The stencil can serve a number of purposes, such as making motorists aware of bicycles potentially in their lane, showing bicyclists the direction of travel, and, with proper placement, reminding bicyclists to bike further from parked cars to prevent "dooring" collisions. Signage used in conjunction with on-street sharrow markings help to clarify their meaning for motorists unfamiliar with them and re-iterate their meaning for motorists who are familiar with them.

Though not always possible, placing the sharrow markings outside of vehicle tire tracks will increase the life of the markings and the long-term cost of the treatment.



Guidance

The 2009 MUTCD notes that shared lane markings should not be placed on roadways with a speed limit over 35 MPH, and that when used the marking should be placed immediately after an intersection and spaced at intervals no greater than 250 feet thereafter. Placing shared lane markings between vehicle tire tracks (if possible) will increase the life of the markings. (See MUTCD Section 9C.07). However, some cities are using a much closer spacing (as close as 75) for SLMs as well as using SLMs for wayfinding (see Section 3).

Bike Lanes

Design Summary

Bike lanes are a popular accommodation for commuter and recreational cyclists.

Designated exclusively for bicycle travel, bike lanes are separated from vehicle travel lanes with striping and also include pavement stencils. Bike lanes are most appropriate on arterial and collector streets where higher traffic volumes and speeds warrant greater separation.

Recommended minimum bike lane widths of:

5 feet, measured from painted edgeline to edge of gutter, on roadways with posted speed limits of 40 mph or greater.

4 feet, measured from painted edgeline to edge of gutter, on roadways with posted speed limits of 35 mph or less.

However, AASHTO and other guidance recommend a five-foot minimum for bike lanes, with four feet only in restricted corridors. In addition, bike lanes are measured to the inside edge of the gutter pan, ensuring smooth pavement rather than a gutter edge in the bike lane.

Discussion

Bike lane pavement markings in Portland, Oregon provide character to the roadway.

Many bicyclists, particularly less experienced riders, are more comfortable riding on a busy street if it has a striped and signed bike lane than if they are expected to share a wide lane. Providing marked facilities such as bike lanes is one way of helping to persuade more tentative riders to try bicycling.

Bike lanes can increase safety and promote proper riding by:

- Defining road space for bicyclists and motorists, reducing the possibility that motorists will stray into the cyclists' path.
- Discouraging bicyclists from riding on the sidewalk.
- Reminding motorists that cyclists have a right to the road.
- Specifying a direction of travel.

In an urban setting, it is crucial to ensure that bike lanes and adjacent parking lanes have sufficient width, so that cyclists have enough room to avoid opened vehicle doors.

Additional Guidance

5 foot bike lanes are currently the recommended minimum and recommended on all arterial roads per the *City of Greenville Design and Specifications Manual.* This includes a 1' concrete gutter, thus reducing the ridable bicycle space to 4'. This should be revised so that there is a minimum of 5' of ridable space with an additional 1' gutter.

High-speed traffic (posted speed of 40 mph or greater) and the presence of large vehicles (truck, bus, or recreational vehicle) are significant factors affecting the acceptability of potential bikeway locations. In locations where these conditions exist, bike lane widths of 5-feet or greater are recommended."

The AASHTO *Guide for the Development of Bicycle Facilities* guideline states that "if used, the bicycle lane symbol marking shall be placed immediately after an intersection and other locations as needed… If the word or symbol pavement markings are used, Bicycle Lane signs shall also be used, but the signs need not be adjacent to every symbol to avoid overuse of the signs."

See also MUTCD Section 9C.04 Markings for Bicycle Lanes.

Guidelines for Bike Lanes

Bike Lane Adjacent to On-Street Parallel Parking

Design Summary

Bike Lane Width:

6' recommended when parking stalls are marked.

5' acceptable if parking not marked (drivers tend to park closer to the curb where parking is unmarked).

7' maximum (greater widths may encourage vehicle loading in bike lane).

Discussion

Bike lanes adjacent to on-street parallel parking are common in the U.S. and can be dangerous for bicyclists if not designed properly. Crashes caused by a suddenly-opened vehicle door are a common hazard for bicyclists using this type of facility. On the other hand, wide bike lanes may encourage the cyclist to ride farther to the right (door zone) to maximize distance from passing traffic. Wide bike lanes may also cause confusion with unloading vehicles in busy areas where parking is typically full.

Some treatments to encourage bicyclists to ride away from the 'door zone' include:

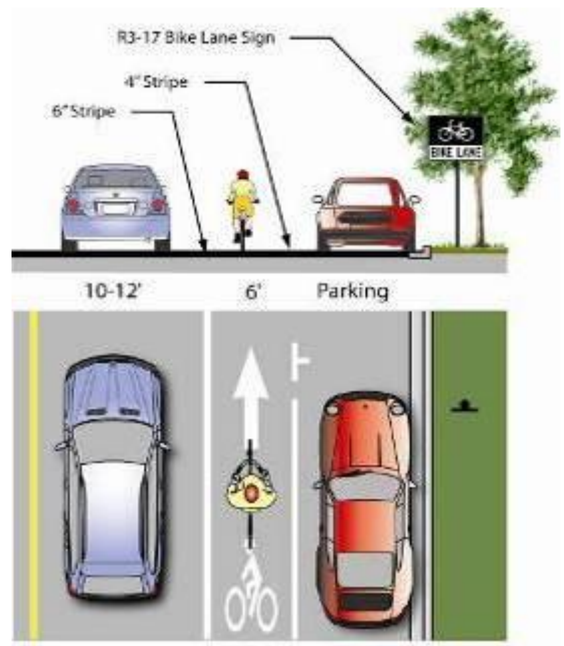
Installing parking "T's" and smaller bike lane stencils placed to the left (see graphic at top).

Provide a buffer zone (preferred design; shown bottom). Bicyclists traveling in the center of the bike lane will be less likely to encounter open car doors. Motorists have space to stand outside the bike lane when loading and unloading.

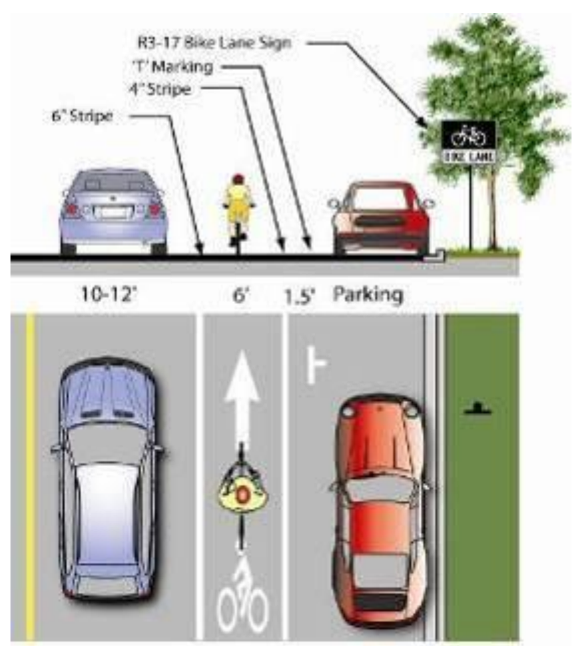
Guidance

From *AASHTO Guide for the Development of Bicycle Facilities*:

> "If parking is permitted, the bike lane should be placed between the parking area and the travel lane and have a minimum width of 5'. Where parking is permitted but a parking stripe or stalls are not utilized, the shared area should be a minimum of 11' without a curb face and adjacent to a curb face. If the parking volume is substantial or turnover is high, an additional 1'- 2' of width is desirable."



Parking 'T' bike lane design.



Parking buffer bike lane design.

Bike Lane Adjacent to On-Street Diagonal Parking

Design Summary

Bike Lane Width:

5' minimum.

White 4" stripe separates bike lane from parking bays.

Parking bays are sufficiently long to accommodate most vehicles (vehicles do not block bike lane).

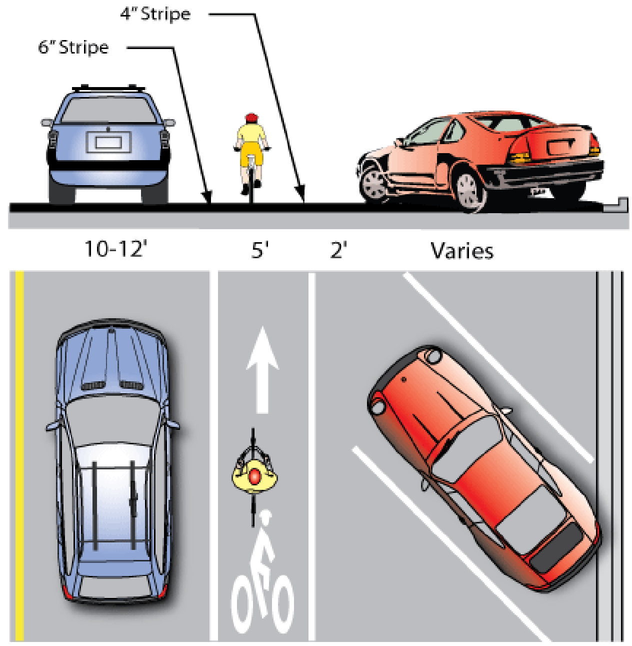
Discussion

In areas with high parking demand such as urban commercial areas, diagonal parking can be used to increase parking supply. Conventional "head-in" diagonal parking is not recommended in conjunction with high levels of bicycle traffic or with the provision of bike lanes as drivers backing out of conventional diagonal parking spaces have poor visibility of approaching bicyclists.

The use of 'back-in diagonal parking' or 'reverse angled parking' is recommended over head-in diagonal parking. This design addresses issues with diagonal parking and bicycle travel by improving sight distance between drivers and bicyclists and has other benefits to vehicles including: loading and unloading of the trunk occurs at the curb rather than in the street, passengers (including children) are directed by open doors towards the curb, no door conflict with bicyclists. While there may be a learning curve for some drivers, using back-in diagonal parking is typically an easier maneuver than conventional parallel parking.

Guidance

This treatment is currently slated for inclusion in the upcoming update of the AASHTO *Guide for the Development of Bicycle Facilities.*



Recommended bike lane adjacent to on-street diagonal parking design.

'Back-in' diagonal parking is safer for cyclists than 'head-in' diagonal parking due to drivers' visibility as they exit the parking spot.

Bike Lane Without On-Street Parking

Design Summary

<u>Bike Lane Width:</u>

4' minimum when no curb & gutter is present.

5' minimum when adjacent to curb and gutter.

<u>Recommended Width:</u>

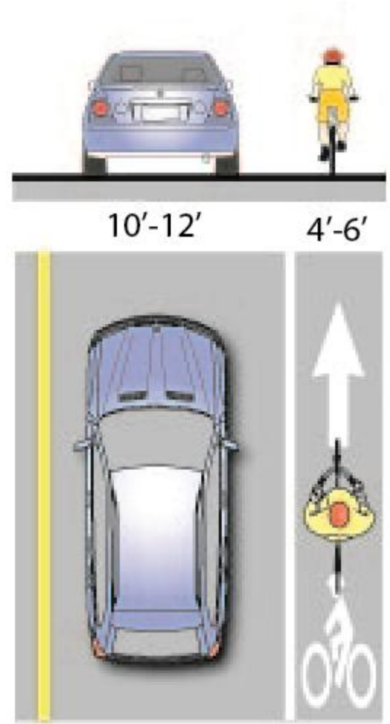
6' where right-of-way allows.

<u>Maximum Width:</u>

6-8' Adjacent to arterials with high travel speeds (45 mph+).

Discussion

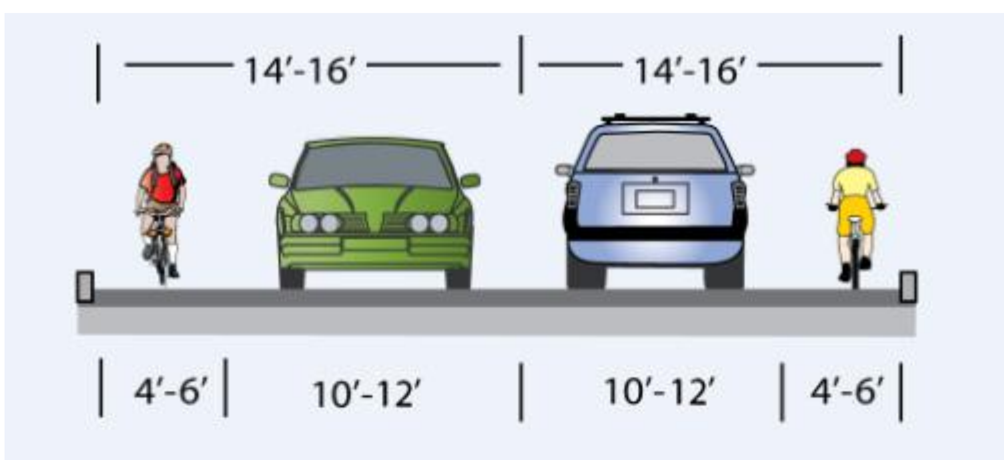
Wider bike lanes are desirable in certain circumstances such as on higher speed arterials (45 mph+) where a wider bike lane can increase separation between passing vehicles and cyclists, bicycle facilities with varying separation from vehicle traffic may be appropriate, depending on the lane configuration and traffic speeds permitted on any given road. Wide bike lanes are also appropriate in areas with high bicycle use. A bike lane width of six to eight feet makes it possible for bicyclists to ride side-by-side or pass each other without leaving the bike lane, increasing the capacity of the lane. Appropriate signing and stenciling is important with wide bike lanes to ensure motorists do not mistake the lane for a vehicle lane or parking lane.



Recommend bike lane without on-street parking design.

Guidance

Two Lane Cross-Section with No Parking*



**Bike lanes may be 4' in width under constrained circumstances*

Bike Lanes at Roundabouts

Design Summary

Reduce the speed differential between circulating motorists and bicyclists (25 mph maximum circulating design speed).

Design approaches/exits to the lowest speeds possible, to reduce the severity of potential collisions with pedestrians.

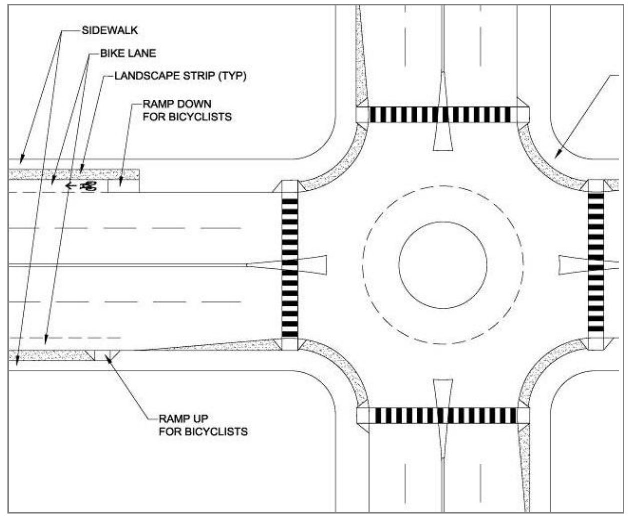
Encourage bicyclists navigating the roundabout like motor vehicles to "take the lane."

Maximize yielding rate of motorists to pedestrians and bicyclists at crosswalks.

Provide separated facilities for bicyclists who prefer not to navigate the roundabout on the roadway.

Indicate to drivers and bicyclists the correct way for them to circulate through the roundabout through appropriately-designed signage, pavement markings and geometric design elements.

Indicate to drivers, bicyclists and pedestrians the right-of-way rules through appropriately -designed signage, pavement markings and geometric design elements.



Recommended bike lane at roundabout design.

(Source: UC Berkeley Traffic Safety Center for Caltrans, Identifying Factors that Determine Bicyclist and Pedestrian-Involved Collision Rates and Bicyclist and Pedestrian Demand at Multi-Lane Roundabouts, 2009).

Discussion

Research indicates that while single-lane roundabouts may benefit bicyclists and pedestrians by slowing traffic, multi-lane roundabouts may significantly increase safety problems for these users. Multi-lane roundabouts pose the following challenges to bicyclists riding in a bike lane:

Bicyclists must take the lane before they enter the roundabout to avoid becoming caught in a "right hook," a situation in which a motorist turns right, across the path of a bicyclist traveling straight. Entry leg speeds must be slow enough for bicyclists to be able to take the lane safely.

Theoretically, once motor vehicle volumes reach a certain magnitude, there are no gaps in traffic large enough to accommodate a bicyclist.

Bicyclists must be able to correctly judge the speed of circulating motorists to find a gap that is large enough for them to safely enter the roundabout. This task is particularly difficult if the circulating motorists are traveling at a much higher speed than the bicyclists. In addition, if circulating speeds in a roundabout are much higher than 20 mph, drivers behind a bicyclist may become impatient, and may pass the bicyclist and turn in front of him, creating more risks for the bicyclist.

As a circulating bicyclist approaches an entry lane, a driver waiting to enter must notice the bicyclist, properly judge the bicyclist's speed, and yield to him/her if necessary. In a location where there are few bicyclists, motorists may not even register that there is a bicyclist approaching. If a bicyclist is hugging the curb, s/he may be outside the motorist's cone of vision.

Guidance

UC Berkeley Traffic Safety Center for Caltrans, Identifying Factors that Determine Bicyclist and Pedestrian-Involved Collision Rates and Bicyclist and Pedestrian Demand at Multi-Lane Roundabouts, 2009

Colored Bike Lanes

Design Summary

<u>Bicycle Lane Width:</u>
4' minimum and 7' maximum.

Colored bike lanes are a common treatment in many European Cities and are starting to gain traction in US cities.

Discussion

A contrasting color for the paving of bicycle lanes can also be applied to continuous sections of roadways. These situations help to better define road space dedicated to bicyclists and make the roadway appear narrower to drivers resulting in beneficial speed reductions.

There are three colors commonly used in bicycle lanes: blue, green, and red. All help the bicycle lane stand out in merging areas. The City of Portland began using blue lanes and changed to green in April 2008. Green is the color being recommended for use.

Colored bicycle lanes require additional cost to install and maintain. Techniques include:

- Paint – less durable and can be slippery when wet
- Colored asphalt – colored medium in asphalt during construction – most durable.
- Colored and textured sheets of acrylic epoxy coating.

Thermoplastic – Expensive, durable but slippery when worn.

Guidance

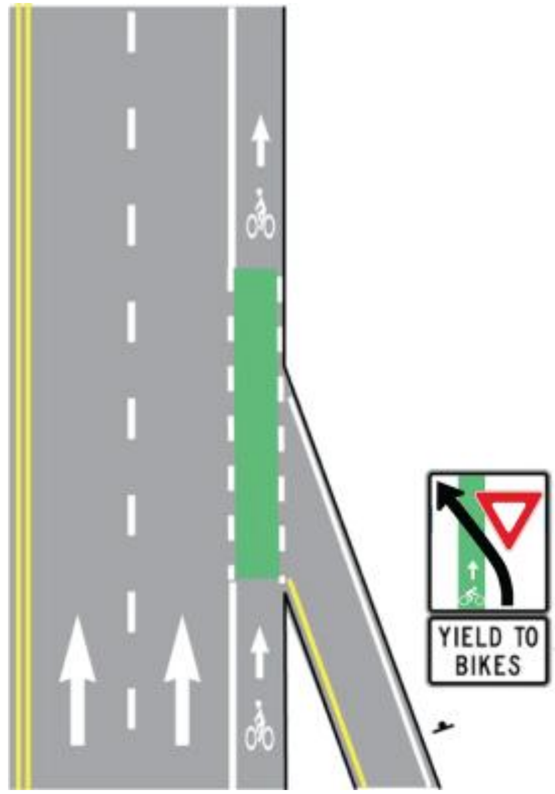
NACTO Urban Bikeway Design Guide: Colored Bike Facilities

Colored Bike Lanes at Interchanges

Design Summary

Bicycle Lane Width:

The bicycle lane width through the interchange should be the same width as the approaching bicycle lane (minimum five feet). Cities in the United States have begun to use the color Green to bring attention to potential conflict points in the road system.



Discussion

On high traffic bicycle corridors non-standard treatments may be desirable over current practices outlined in the MUTCD. Dashed bicycle lane lines with or without colored bicycle lanes may be applied to provide increased visibility for bicycles in the merging area.

Guidance

This treatment is not currently present in any State or Federal design standards

City of Chicago - Green Pavement Markings for Bicycle Lanes (Ongoing) - FHWA Experiment No. 9-77(E)

Portland's Blue Bicycle Lanes:

http://www.portlandonline.com/shared/cfm/image.cfm?id=58842

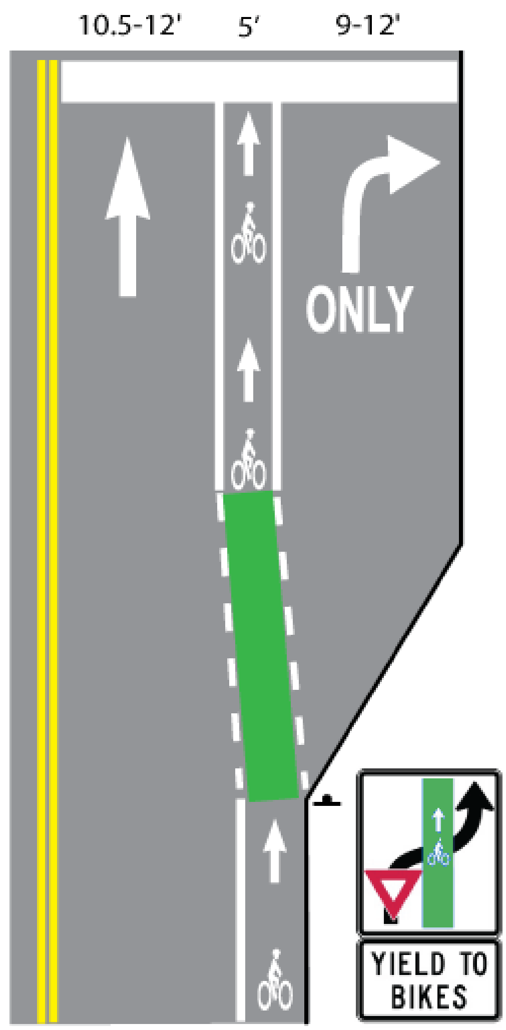
"The color green shall be used to minimize confusion with other standard traffic control markings." - **NACTO *Urban Bikeway Design Guide***

Colored Bike Lanes in Conflict Areas

Design Summary

Bicycle Lane Width:

The bicycle lane width through the interchange should be the same width as the approaching bicycle lane (minimum five feet).



Discussion

Some cities in the United States are using colored bicycle lanes to guide bicyclists through major vehicle/bicycle conflict points.

Color Considerations:

There are three colors commonly used in bicycle lanes: blue, green, and red. All help the bicycle lane stand out in merging areas. The City of Portland began using blue lanes and changed to green in April 2008. Green is the color being recommended for use.

Guidance

This treatment is not currently present in any State or Federal design standards

City of Chicago - Green Pavement Markings for Bicycle Lanes (Ongoing) - FHWA Experiment No. 9-77(E)

Portland's Blue Bicycle Lanes

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"The color green shall be used to minimize confusion with other standard traffic control markings." - NACTO *Urban Bikeway Design Guide*

Retrofitting Existing Streets with Bike Lanes

Introduction

Most major streets in Greenville are characterized by conditions (e.g., high vehicle speeds and/or volumes) for which dedicated bike facilities are appropriate to accommodate safe and comfortable riding. Although opportunities to add bike lanes through roadway widening may exist in some locations, most major streets in Greenville pose physical and other constraints requiring street retrofit measures within existing curb-to-curb widths. Providing bicycle facilities on streets designed primarily for motor vehicle traffic can be challenging to implement, depending on the physical layout of the street. In some cases, bicycle facilities may be desirable on streets with higher vehicle speed and volumes. Placing bicycle facilities on these streets allows for a predictable environment for motorists and bicyclists by clarifying the appropriate position for each user on a roadway. Though opportunities to add bicycle facilities through roadway widening may exist in some locations, most major streets pose physical and other constraints requiring street retrofit measures within existing curb-to-curb widths. As a result, it may be necessary to reallocate existing street width through striping modifications to accommodate dedicated bicycle facilities. As a result, many of the recommended measures effectively reallocate existing street width through striping modifications to accommodate dedicated bike lanes. The measures covered in this section include addition of a paved shoulder to an existing road, lane narrowing on an existing road, lane reconfiguration on an existing road, and on- street parking reduction,

While largely intended for major streets, these measures may be appropriate on some lower-order streets where bike lanes would best accommodate cyclists.

Above shows the before and after of lane narrowing along an excessively wide roadway. The resulting configuration not only defines space for bicyclists, but creates a safer environment for motorists and pedestrians as well by reducing the tendency for motorists to drive fast.

Paved Shoulder

Design Summary

<u>Bike Lane Width</u>

6′ preferred.

4′ minimum (see bike lane guidance).

Discussion

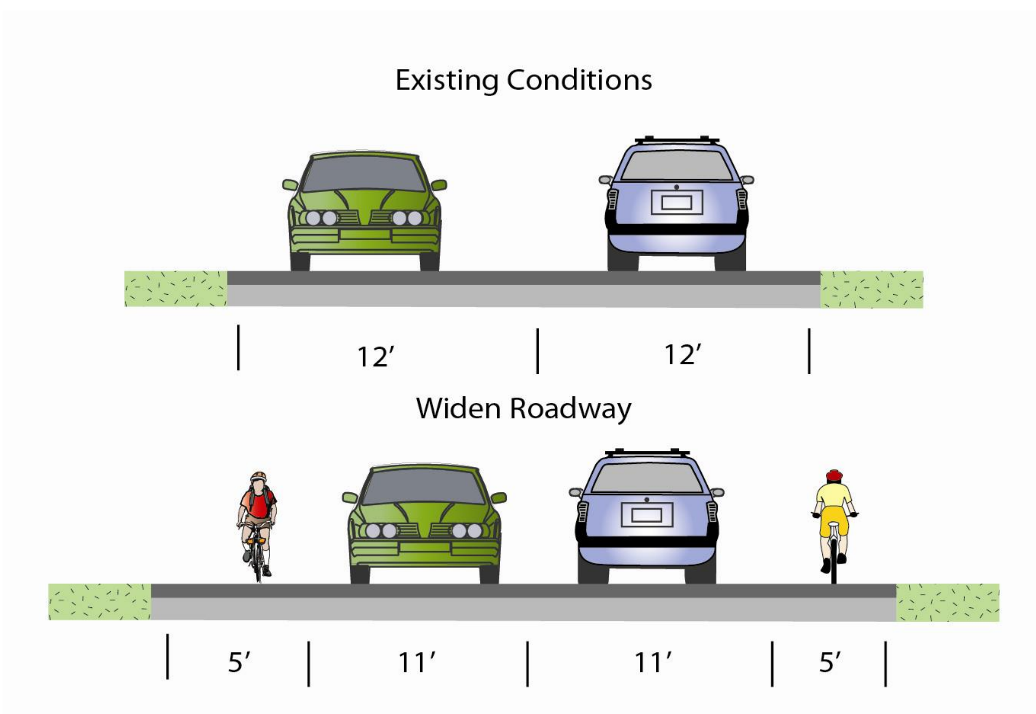
Bike lanes could be accommodated on several streets with excess right-of-way through shoulder widening. Although street widening incurs higher expenses compared with re-striping projects, bike lanes could be added to streets currently lacking curbs, gutters and sidewalks without the high costs of major infrastructure reconstruction.

As a long-term measure, the City of Greenville should find opportunities to add bike lanes to other major streets where they are needed. Opportunities include adding bike lanes as streets and bridges are widened for additional auto capacity or as property development necessitates street reconstruction.

Roadway widening is preferred on roads lacking curbs, gutters and sidewalks

Guidance

Example of roadway widening to accommodate bike lanes and street parking



Lane Narrowing

Design Summary

Vehicle Lane Widths

Before: 12 to 15 feet; after: 10 to 11 feet.

Bike Lane Width

See bike lane design guidance.

Discussion

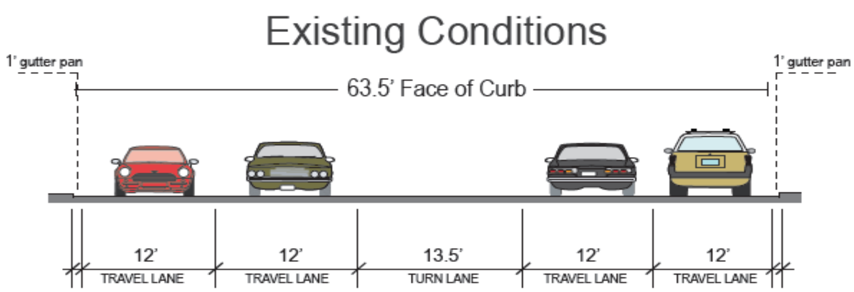
Lane narrowing utilizes roadway space that exceeds minimum standards to create the needed space to provide bike lanes. Some roadways in Greenville may have existing lanes that are wider than those prescribed in local and national roadway design standards, or which are not marked. Most standards allow for the use of 11-foot and sometimes 10-foot wide travel lanes to create space for bike lanes.

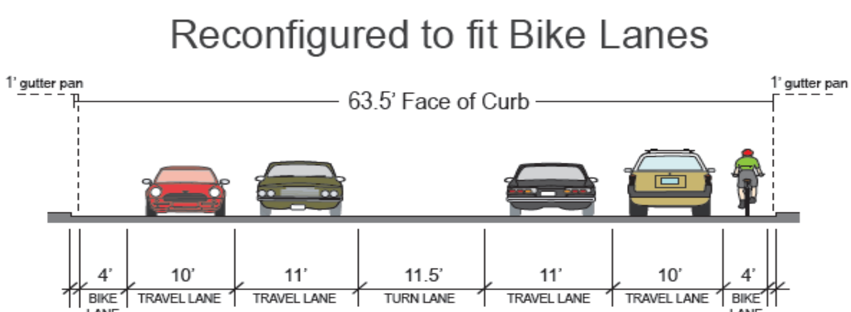
Special consideration should be given to the amount of heavy vehicle traffic and horizontal curvature before the decision is made to narrow travel lanes. Center turn lanes can also be narrowed in some situations to free up pavement space for bike lanes.

This street previously had 13' lanes, which were narrowed to accommodate bike lanes without removing a lane.

Guidance

Example of vehicle travel lane narrowing to accommodate bike lanes.





Road Diet (Lane Reconfiguration)

Design Summary

Vehicle Lane Widths

Width depends on project. No narrowing may be needed if a lane is removed.

Bike Lane Width

See bike lane design guidance.

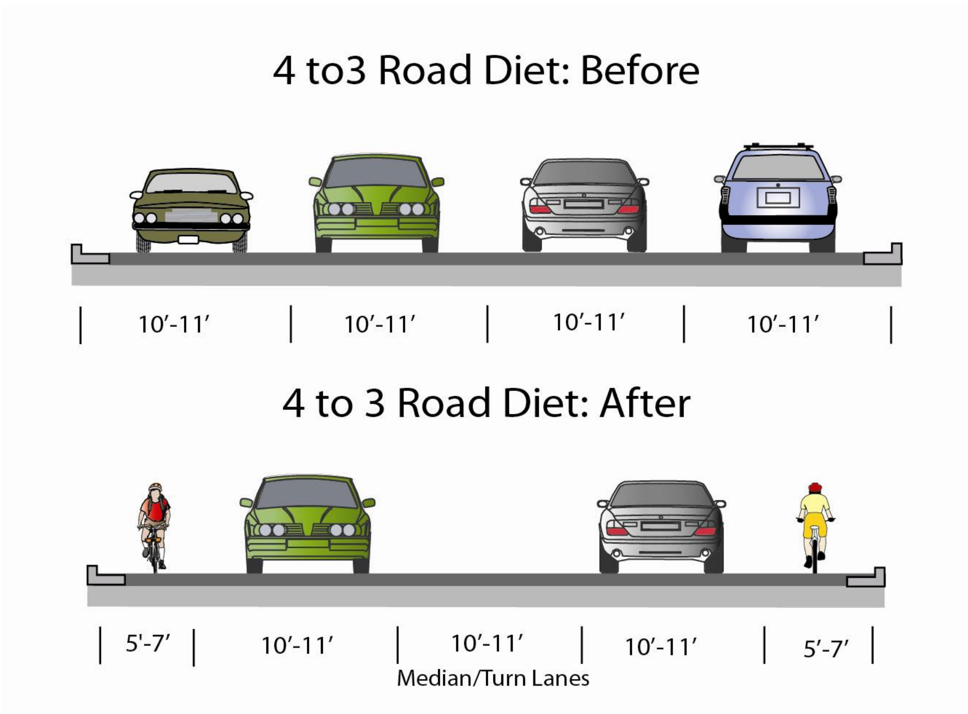
Discussion

In most cases, the removal of a single travel lane will provide sufficient space for bike lanes on both sides of a street. Streets with excess vehicle capacity provide opportunities for bike lane retrofit projects. Depending on a street's existing configuration, traffic operations, user needs, and safety concerns, various lane reduction configurations exist. For instance, a four-lane street (with two travel lanes in each direction) could be modified to include one travel lane in each direction, a center turn lane, and bike lanes. Prior to implementing this measure, a traffic analysis should identify impacts.

This treatment is slated for inclusion in the update to the AASHTO *Guide for the Development of Bicycle Facilities.*

West Washington Street in Greenville was re-striped to convert four vehicle travel lanes into three travel lanes with bike lanes.

Guidance



Example of vehicle travel lane reconfiguration to accommodate bike lanes

Parking Reduction

Design Summary

<u>Vehicle Lane Widths</u>

Width depends on project. No narrowing may be needed depending on the width of the parking lane to be removed.

<u>Bike Lane Width</u>

See bike lane design guidance.

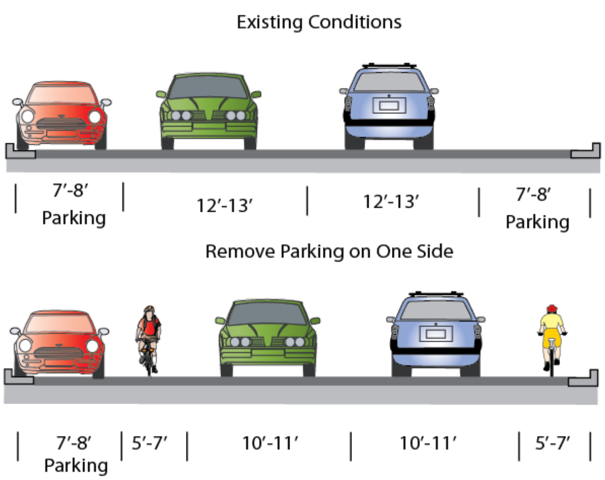
Some streets may not require parking on both sides

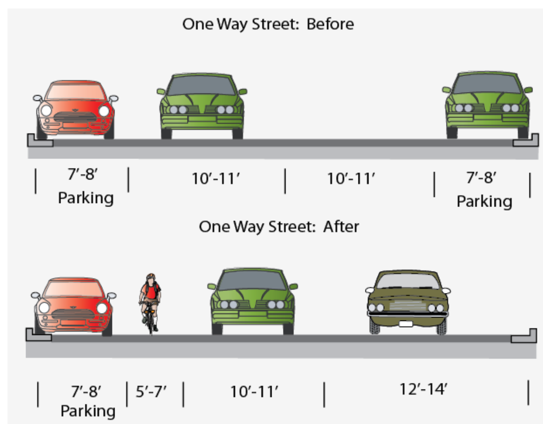
Discussion

Bike lanes could replace one or more on-street parking lanes on streets where excess parking exists and/or the importance of bike lanes outweighs parking needs. For instance, parking may be needed on only one side of a street (as shown below and at right). Eliminating or reducing on-street parking also improves sight distance for cyclists in bike lanes and for motorists on approaching side streets and driveways. Prior to reallocating on-street parking for other uses, a parking study should be performed to gauge demand and to evaluate impacts to people with disabilities.

Guidance

Example of parking removal to accommodate bike lanes.





Separated Bikeways

Design Summary

Shared-use paths can provide a desirable facility particularly for novice riders, recreational trips, and cyclists of all skill levels preferring separation from traffic. Shared-use paths should generally provide new travel opportunities.

Discussion

Shared-use paths serve bicyclists and pedestrians and provide additional width over a standard sidewalk. Facilities may be constructed adjacent to roads, through parks, or along linear corridors such as active or abandoned railroad lines or waterways. Regardless of the type, paths constructed next to the road must have some type of vertical (e.g., curb or barrier) or horizontal (e.g., landscaped strip) buffer separating the path area from adjacent vehicle travel lanes.

Shared-use paths (also referred to as "trails" and "multi-use paths"), such as Greenville's Swamp Rabbit Trail, are often viewed as recreational facilities, but they are also important corridors for utilitarian trips.

Elements that enhance shared-use path design include:

Providing frequent access points from the local road network; if access points are spaced too far apart, users will have to travel out of direction to enter or exit the path, which will discourage use.

Placing directional signs to direct users to and from the path.

Building to a standard high enough to allow heavy maintenance equipment to use the path without causing it to deteriorate.

Limiting the number of at-grade crossings with streets or driveways.

Terminating the path where it is easily accessible to and from the street system, preferably at a controlled intersection or at the beginning of a dead-end street. If poorly designed, the point where the path joins the street system can put pedestrians and cyclists in a position where motor vehicle drivers do not expect them.

Identifying and addressing potential safety and security issues up front.

Whenever possible, and especially where heavy use can be expected, separate bicycle and pedestrian ways should be provided to reduce conflicts.

Providing accessible parking space(s) at trailheads and access points.

Additional Guidance

Shared –use paths should be constructed according to the AASHTO *Guide for the Development of Bicycle Facilities*. Where possible, shared-use paths should be designed according to ADA standards. Constructing trails may have limitations that make meeting ADA standards difficult and sometimes prohibitive. Prohibitive impacts include harm to significant cultural or natural resources, a significant change in the intended purpose of the trail, requirements of construction methods that are against federal, state or local regulations, or presence of terrain characteristics that prevent compliance.

Cycletrack

Design Summary

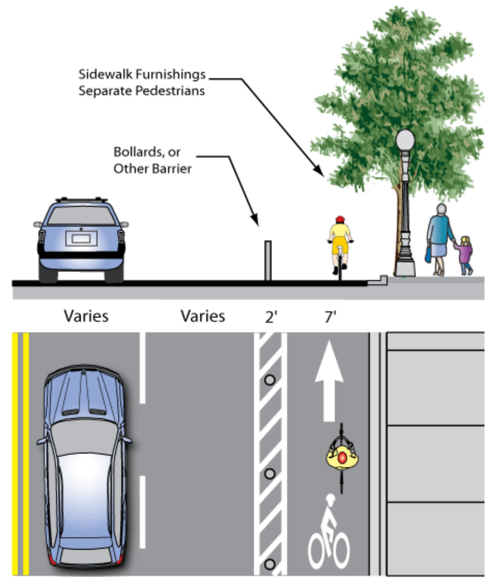
<u>Cycle Track Width:</u>

7 feet minimum to allow passing and obstacle avoidance

12 feet minimum for two-way facility

Discussion

A cycle track is a hybrid type bicycle facility that combines the experience of a separated path with the on-street infrastructure of a conventional bicycle lane. Cycle tracks have different forms, but all share common elements. Cycle tracks provide space that is intended to be exclusively or primarily for bicycles, and is separated from vehicle travel lanes, parking lanes and sidewalks. Cycle tracks can be either one-way or two-way, on one or both sides of a street, and are separated from vehicles and pedestrians by pavement markings or coloring, bollards, curbs/medians or a combination of these elements.



Recommended Design – No Parking

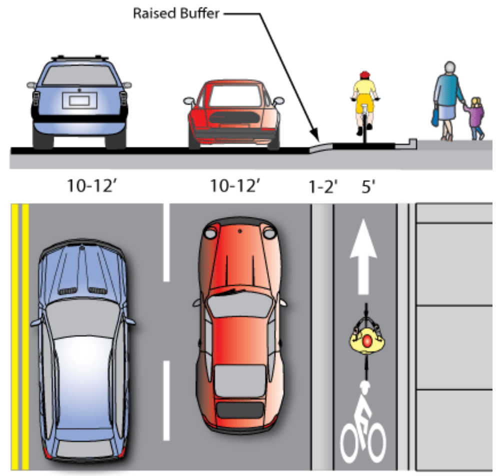
Guidance

NACTO Urban Bikeway Design Guide

Crow Design Manual for Bicycle Traffic - Chapter 5

Recommended Design – Two-Way Cycletrack

Raised Bicycle Lanes



Design Summary

Bicycle Lane Width:

5 feet minimum. Bicycle lane should drain to street. Drainage grates should be in travel lane.

Mountable Curb Design:

Mountable curb should have a 4:1 or flatter slope and have no lip that could catch bicycle tires.

Signage & Striping:

Same as traditional Class II bicycle lanes

Discussion

Raised bicycle lanes are bicycle lanes that have a mountable curb separating them from the adjacent travel lanes. Raised bicycle lanes provide an element of physical separation from faster moving vehicle traffic. For drivers, the mountable curb provides a visual and tactile reminder of where the bicycle lane is. For bicyclists the mountable curb makes it easy to leave the bicycle lane if necessary, when passing another bicyclist, or to merge to the left for turning movements. The raised bicycle lane should return to level grade at intersections.

Raised bicycle lanes cost more than traditional bicycle lanes and typically require a separate paving operation. Maintenance costs are lower as the bicycle lane receives no vehicle wear and resists debris accumulation.

Raised bicycle lanes work well adjacent to higher speed roadways with few driveways.

Guidance

This treatment is not currently present in any U.S. State or Federal design manuals

Crow Design Manual for Bicycle Traffic - Chapter 5

Buffered Bicycle Lanes

Design Summary

Bicycle Lane Width:

5 feet minimum. Bicycle lane should drain to street. Drainage grates should be in travel lane.

Signage & Striping:

Same as traditional Class II bicycle lanes

Discussion

Provides cushion of space to mitigate friction with motor vehicles on streets with frequent or fast motor vehicle traffic. Buffered Bike lanes allow bicyclists to pass on another or avoid obstacles without encroaching into the travel lane.

These facilities increase motorist shy distance from bicyclist in the bike lane and reduce the risk of "dooring" compared to a conventional bike lane.

Buffered bike lanes require additional roadway space and maintenance.

Guidance

This treatment is not currently present in any U.S. State or Federal design manuals

Crow Design Manual for Bicycle Traffic - Chapter 5

Trails Along Roadways

Design Summary

Where a shared-use path must be adjacent to a roadway, a five foot minimum buffer should separate the path from the edge of the roadway, or a physical barrier of sufficient height should be installed.

Shared use paths may be considered along roadways under the following conditions:

The path will generally be separated from all motor vehicle traffic.

Bicycle and pedestrian use is anticipated to be high.

To provide continuity with an existing path through a roadway corridor.

The path can be terminated at each end onto streets or trails with good bicycle and pedestrian facilities.

There is adequate access to local cross-streets and other facilities along the route.

Any needed grade separation structures do not add substantial out-of-direction travel.

Trails directly adjacent to roadways, such as the Swamp Rabbit Trail's East Faris Road section, offer advantages, but can be challenging for users at roadway intersections.

Discussion

Concerns about shared use paths directly adjacent to roadways (e.g., with minimal or no separation) are:

Half of bicycle traffic may ride against the flow of vehicle traffic, contrary to the rules of the road.

When the path ends, cyclists riding against traffic tend to continue to travel on the wrong side of the street, as do cyclists who are accessing the path. Wrong-way bicycle travel is a major cause of crashes.

At intersections, motorists crossing the path often do not notice bicyclists approaching from certain directions, especially where sight distances are poor.

Bicyclists are required to stop or yield at cross-streets and driveways, unless otherwise posted.

Stopped vehicles on a cross-street or driveway may block the path.

Because of the closeness of vehicle traffic to opposing bicycle traffic, barriers are often necessary to separate motorists from cyclists. These barriers serve as obstructions, complicate facility maintenance and waste available right-of-way.

Paths directly adjacent to high-volume roadways diminish users' experience by placing them in an uncomfortable environment.

As bicyclists gain experience and realize some of the advantages of riding on the roadway, some riders stop using paths adjacent to roadways. Bicyclists may also tend to prefer the roadway as pedestrian traffic on the shared use path increases due to its location next to an urban roadway. When designing a bikeway network, the presence of a nearby or parallel path should not be used as a reason to not provide adequate shoulder or bike lane width on the roadway, as the on-street bicycle facility will generally be superior to the "sidepath" for experienced cyclists and those who are cycling for transportation purposes. Bike lanes should be provided as an alternate (more transportation-oriented) facility whenever possible.

Guidance

The AASHTO *Guide for the Development of Bicycle Facilities* generally recommends against the development of trails adjacent to roadways.

Bicycle Boulevards

Design Summary

Bicycle Boulevards are generally installed on minor or local roadways and serve as bicycle routes. No design standard exists. See following pages for additional guidance.

Discussion

On Bicycle Boulevards, Neighborhood Greenways, or bicycle routes, it is important to provide a benefit to the bicyclist by choosing the route. Frequently this benefit is composed of reduced travel time, lower motor vehicle traffic volumes and/or reduced motor vehicle speeds. Ideally, the bicyclist should not be making frequent stops. The Bicycle Boulevard should be watched closely following treatment to see if there is an increase in vehicle trips along the route as many motorists may take advantage of fewer stops thereby reducing the effectiveness of the facility for bicycles. If motor vehicle ADT increases, treatments may be considered such as diagonal diverters, one-way closures, chicanes, chokers and other applicable treatments to preserve bicycle permeability and limit through vehicle access.

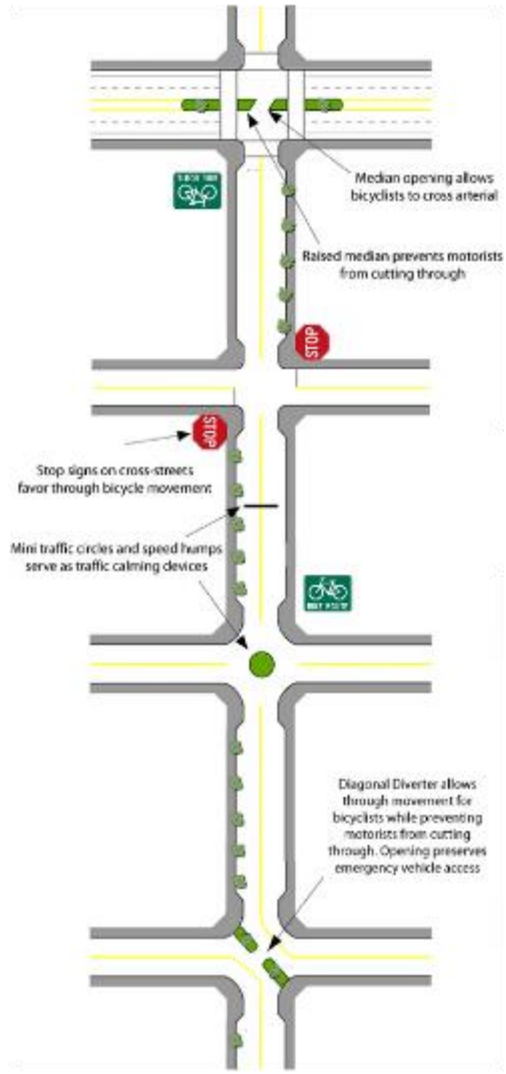
Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook.* www.ibpi.usp.pdx.edu/guidebook.php

City of Berkeley. (2000). Bicycle Boulevard Design Tools and Guidelines.

AASHTO Guide for the Development of Bicycle Facilities.

MUTCD.



Level 1: Signage

Design Summary

Signing is a cost-effective yet highly-visible treatment that can improve the riding environment on a bicycle boulevard.

The City should maintain consistent signage and paint markings throughout the region.

Discussion

<u>Wayfinding Signs (Can be non-standard treatment)</u>

Wayfinding signs are typically placed at key locations leading to and along bicycle boulevards, including where multiple routes intersect and at key bicyclist "decision points." Wayfinding signs displaying destinations, distances and "riding time" can dispel common misperceptions about time and distance while increasing users' comfort and accessibility to the boulevard network.

Wayfinding signs also visually cue motorists that they are driving along a bicycle route and should correspondingly use caution. Note that too many signs tend to clutter the right-of-way, and it is recommended that these signs be posted at a level most visible to bicyclists and pedestrians, rather than per vehicle signage standards.

<u>Warning signs</u>

Warning signs advising motorists to "share the road" and "watch for bicyclists" may also improve bicycling conditions on shared streets. These signs are especially useful near major bicycle trip generators such as schools, parks and other activity centers. Warning signs should also be placed on major streets approaching bicycle boulevards to alert motorists of bicyclist crossings.

Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook.* www.ibpi.usp.pdx.edu/guidebook.php

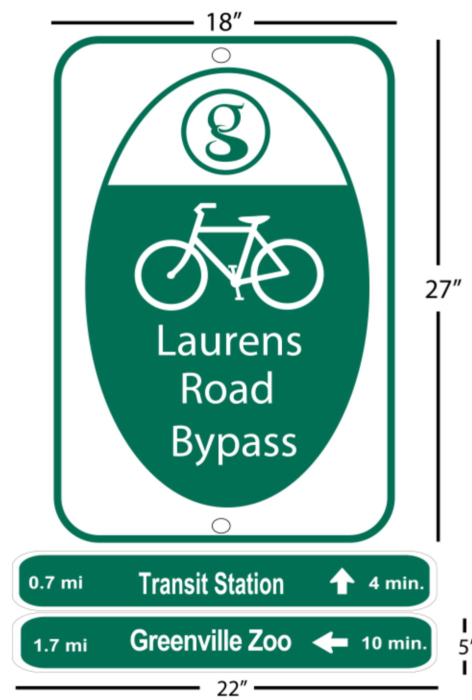
City of Berkeley. (2000). Bicycle Boulevard Design Tools and Guidelines.

AASHTO Guide for the Development of Bicycle Facilities.

MUTCD.

Sample bicycle boulevard signage.

Below: Wayfinding signs help bicyclists stay on designated bicycle routes.



Level 1 continued: On-Street Bikeway Signage

Design Summary

Destinations for on-street signage can include:

On-street bikeways	Civic/community destinations
Commercial centers	Local parks and trails
Regional parks and trails	Hospitals
Public transit sites	Schools

Recommended uses for on-street signage include:

Confirmation signs confirm that a cyclist is on a designated bikeway and can include destinations or distances, but not directional arrows.

Turn signs indicate where a bikeway turns from one street onto another street. Turn signs are located on the near-side of intersections.

Decision signs mark the junction of two or more bikeways. Decision signs are located on the near-side of intersections. They can include destinations and their associated directional arrows, but not distances.

Discussion

Signage can help by:

- Familiarizing users with the pedestrian and bicycle network
- Identifying the best routes to destinations.
- Addressing misperceptions about time and distance.
- Overcoming a "barrier to entry" for infrequent cyclists or pedestrians
- Bypassing major roadways that lack bicycle facilities

Wayfinding signs also visually cue motorists that they are driving along a bicycle route and should use caution. Signs are typically placed at key locations leading to and along bicycle routes, including the intersection of multiple routes. Too many road signs tend to clutter the right-of-way, and it is recommended that these signs be posted at a level most visible to bicyclists and pedestrians, rather than per vehicle signage standards. Signs are typically placed at key locations leading to and along bicycle routes, including the intersection of multiple routes. Additional recommended guidelines include:

Place the closest destination to each sign in the top slot. Destinations that are further away can be placed in slots two and three. This allows the nearest destination to 'fall off' the sign and subsequent destinations to move up the sign as the bicyclist approaches.

Use pavement markings to help reinforce routes and directional signage. Markings, such as bicycle boulevard symbols, may be used in addition to or in place of directional signs along bike routes to help cyclists navigate difficult turns and provide route reinforcement.

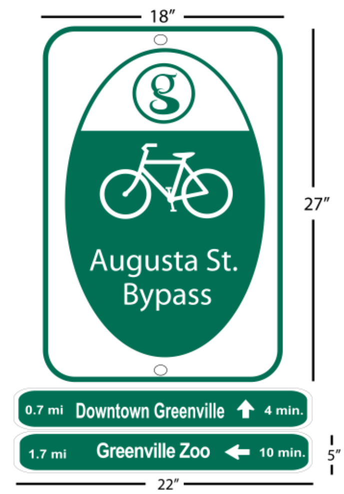
Guidance

City of Oakland. (2009). *Design Guidelines for Bicycle Wayfinding Signage*.

City of Portland (2002). *Bicycle Network Signing Project*.

Greenville bike route sign.

Wayfinding that includes distance and time can address misperceptions about time and distance.



Example of sponsored bikeway signs in Bentonville AR.

Level 2: Pavement Markings & Route Signage

Design Summary

Pavement markings are used in conjunction with on-street signage to compliment bicycle network wayfinding

Pavement markings should be installed to provide continuity through a route and to alert bicyclists of intersecting bike routes/facilities

Discussion

Pavement markings have recently been used across the United States as a way to orient bicyclists throughout a city bike route network. These facilities are most frequently used on low-volume, residential streets or in conjunction with the development of a bicycle boulevard or neighborhood greenway.

<u>Circle/Arrow</u>

Directional pavement markings provide notification to bicyclists on proper road positioning, and notify users of routing options as routes intersect with the greater bike network.

The first generation of pavement stencils that provided directional route information were 12" circles with an arrow indicating the direction the route followed. These are useful where routes end at a T-junction or as a road "jogs" at intersecting streets.

<u>"Broken Sharrow"</u>

The City of Portland has introduced a new treatment, replacing the circle and arrow marker with the "Broken Sharrow." The Broken Sharrow utilizes the stenciling used in the Shared Lane Marking symbol with directional arrow/chevrons that direct bicyclists to adjoining or a continued facility. The added benefit of the Broken Sharrow is that it serves the dual purpose of wayfinding and instruction on ideal lane positioning. Initial feedback indicates that bicyclists find the Broken Sharrow easier to see on the road than the smaller circle/arrow treatments.

Guidance

- Portland Bureau of Transportation
- NACTO Urban Bikeway Design Guide

Directional pavement marker

Basic layout of the Bike Route pavement stencil

The City of Portland's updated bicycle route stencil, the "Broken Sharrow"

Level 2 continued: Bicycle Boulevard Pavement Markings

Design Summary

Use pavement markings to designate bicycle boulevards and provide directional/wayfinding information

Discussion

On-Street Parking Delineation

Delineating on-street parking spaces with paint or other materials clearly indicates where a vehicle should be parked, and can discourage motorists from parking their vehicles too far into the adjacent travel lane. This helps cyclists by maintaining a wide enough space to safely share a travel lane with moving vehicles while minimizing the need to swerve farther into the travel lane to maneuver around parked cars.

In addition to benefiting cyclists, delineated parking spaces also promote the efficient use of on-street parking by maximizing the number of spaces in high-demand areas.

Centerline Striping Removal

Automobiles have an easier time passing cyclists on roads without centerline stripes for the majority of the block length. If vehicles cannot easily pass each other using the full width of the street, it is likely that there is too much traffic for the subject street to be a successful bicycle boulevard. In addition, not striping the centerline reduces maintenance costs. Berkeley paints a double yellow centerline from 40-50' at uncontrolled or stop-controlled intersections, as well as pavement reflectors to identify the center of the street.

Directional Pavement Markings (Non-standard treatment)

Directional pavement markings (also known as "bicycle boulevard markings" or "breadcrumbs") lead cyclists along a boulevard and reinforce that they are on a designated route. Markings can take a variety of forms, such as small bicycle symbols placed every 600-800 feet along a linear corridor, as previously used on Portland, Oregon's boulevard network.

Recently, jurisdictions have been using larger, more visible pavement markings. Shared lane markings could be used as bicycle boulevard markings, as Portland, OR has moved towards using. See shared lane marking guidelines for additional information on this treatment.

In Berkeley, California, non-standard pavement markings include larger-scale lettering and stencils to clearly inform motorists and bicyclists of a street's function as a bicycle boulevard.

Bicycle boulevard directional marker.

City/County proposed pavement markings for on-street bike routes leading to the Swamp Rabbit Trail.

Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook.* www.ibpi.usp.pdx.edu/guidebook.php

City of Berkeley. (2000). Bicycle Boulevard Design Tools and Guidelines.

AASHTO Guide for the Development of Bicycle Facilities.

MUTCD.

Level 3: Bicycle Boulevard Traffic Calming

Design Summary

Traffic calming treatments reduce vehicle speeds to the point where they generally match cyclists' operating speeds, enabling motorists and cyclists to safely co-exist on the same facility.

Discussion

Chicanes (Non-standard treatment)

Chicanes are a series of raised or delineated curb extensions on alternating sides of a street forming an S-shaped curb, which reduce vehicle speeds through narrowed travel lanes. Chicanes can also be achieved by establishing on-street parking on alternate sides of the street. These treatments are most effective on streets with narrower cross-sections.

Mini Traffic Circles

Mini traffic circles are raised or delineated islands placed at intersections, reducing vehicle speeds through tighter turning radii and narrowed vehicle travel lanes (see right). These devices can effectively slow vehicle traffic while facilitating all turning movements at an intersection. Mini traffic circles can also include a paved apron to accommodate the turning radii of larger vehicles like fire trucks or school buses.

Speed Humps

Shown right, speed humps are rounded raised areas of the pavement requiring approaching motor vehicles to reduce speed. These devices also discourage thru vehicle travel on a street when a parallel route exists.

Speed humps should never be constructed so steep that they may cause a bicyclist to lose control of the bicycle or be distracted from traffic. In some cases, a gap could be provided, whereby a bicyclist could continue on the level roadway surface, while vehicles would slow down to cross the barrier.

Chicanes require all vehicles to reduce their speeds.

Traffic circles provide an opportunity for landscaping, but visibility should be maintained.

Speed humps are a common traffic calming treatment. Change photo to show a bicycle friendly hump with a gap for bicyclists.

Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook.* www.ibpi.usp.pdx.edu/guidebook.php

City of Berkeley. (2000). *Bicycle Boulevard Design Tools and Guidelines.*

AASHTO *Guide for the Development of Bicycle Facilities.*

Level 3 continued: Minor Unsignalized Intersections

Design Summary

To encourage use of the boulevard and improve cyclists' safety, reduce bicycle travel time by eliminating unnecessary stops and improving intersection crossings.

Discussion

Stop Sign on Cross-Street

Unmarked intersections are dangerous for bicyclists, because cross-traffic may not be watching for cyclists. Stop sign on cross streets require crossing motorists to stop and proceed when safe. Stop signs are a relatively inexpensive treatment that is quite effective at minimizing bicycle and cross-vehicle conflicts. However, placing stop signs at all intersections along bicycle boulevards may be unwarranted as a traffic control device.

Stop signs effectively minimize conflicts along bicycle boulevards.

Curb Extensions and High-Visibility Crosswalks

This treatment is appropriate near activity centers with large amounts of pedestrian activity, such as schools or commercial areas. Curb extensions should only extend across the parking lane and not obstruct bicyclists' path of travel or the travel lane. Curb extensions and high-visibility crosswalks both calm traffic and also increase the visibility of pedestrians waiting to cross the street, although they may impact on-street parking.

Curb extensions can be a good location for pedestrian amenities, including street trees.

Bicycle Forward Stop Bar (Non-standard treatment)

A second stop bar for cyclists placed closer to the centerline of the cross street than the first stop bar increases the visibility of cyclists waiting to cross a street. This treatment is typically used with other crossing treatments (i.e. curb extension) to encourage cyclists to take full advantage of crossing design. They are appropriate at unsignalized crossings where fewer than 25 percent of motorists make a right turn movement.

Bicycle forward stop bars encourage cyclists to wait where they are more visible.

Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook.*

City of Berkeley. (2000). Bicycle Boulevard Design Tools and Guidelines.

AASHTO Guide for the Development of Bicycle Facilities.

MUTCD.

Level 3 continued: Major Unsignalized Intersections

Design Summary

Increase crossing opportunities with medians and refuge islands

Medians on bicycle boulevards can provide space for a bicyclist to wait.

Discussion

Medians/Refuge Islands

A crossing island can be provided to allow cyclists to cross one direction of traffic at a time when gaps in traffic allow. The crossing island should be at least 8' wide; narrower medians can accommodate bikes if the holding area is at an acute angle to the major roadway. Crossing islands can be placed in the middle of the intersection, prohibiting left and thru vehicle movements.

Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook.*

City of Berkeley. (2000). *Bicycle Boulevard Design Tools and Guidelines.*

AASHTO *Guide for the Development of Bicycle Facilities.*

NACTO *Urban Bikeway Design Guide*

Level 3 continued: Offset Intersections

Design Summary

Provide turning lanes or pockets at offset intersection, providing cyclists with a refuge to make a two-step turn.

Bike turn pockets - 5'wide, with a total of 11' required for both turn pockets and center striping.

Example of a bicycle left-turn pocket.

Discussion

Offset intersection can be challenging for cyclists, who need to transition onto the busier cross-street in order to continue along the boulevard.

Bicycle Left-Turn Lane (Non-standard treatment)

Bicycle left-turn lanes allow the crossing to be completed in two phases. The bicyclist executes a right-hand turn onto the cross-street, and then waits in a delineated left-turn lane if necessary. The bike turn pockets should be at least 5' wide, total of 11' for turn pockets and center striping.

Bicycle Left Turn Pocket (Non-standard treatment)

A bike-only left-turn pocket permits bicyclists to make left turns while restricting vehicle left turns. Signs should prohibit motorists from turning. Because of the restriction on vehicle left-turning movements, this treatment also acts as traffic diversion.

This bike-only left-turn pocket guides cyclists along a popular bike route.

Guidance

Alta and IBPI. *Bicycle Boulevard Planning and Design Handbook.*

AASHTO *Guide for the Development of Bicycle Facilities.*

Level 4: Bicycle Boulevard Traffic Diversion

Design Summary

Traffic diversion treatments maintain thru-bicycle travel on a street while physically restricting thru vehicle traffic.

Traffic diversion is most effective when higher-order streets can sufficiently accommodate the diverted traffic associated with these treatments.

Discussion

Choker Entrances (Non-standard treatment)

Choker entrances are intersection curb extensions or raised islands allowing full bicycle passage while restricting vehicle access to and from a bicycle boulevard. When they approach a choker entrance at a cross-street, motorists on the bicycle boulevard must turn onto the cross-street while cyclists may continue forward. These devices can be designed to permit some vehicle turning movements from a cross-street onto the bicycle boulevard while restricting other movements.

Traffic Diverters (Non-standard treatment)

Similar to choker entrances, traffic diverters are raised features directing vehicle traffic off the bicycle boulevard while permitting thru travel.

Advantages:

Provides safe refuge in the median of the major street so that bicyclists only have to cross one direction of traffic at a time; works well with signal-controlled traffic platoons coming from opposite directions.

Provides traffic calming and safety benefits by preventing left turns and/or thru traffic from using the intersection.

Disadvantages:

Potential motor vehicle impacts to major roadways, including lane narrowing, loss of some on-street parking and restricted turning movements.

Crossing island may be difficult to maintain and may collect debris.

Guidance

Alta Planning + Design and IBPI. *Bicycle Boulevard Planning and Design Handbook*. www.ibpi.usp.pdx.edu/guidebook.php

City of Berkeley. (2000). *Bicycle Boulevard Design Tools and Guidelines.*

AASHTO *Guide for the Development of Bicycle Facilities.*

Choker entrances prevent vehicular traffic from turning from a main street onto a traffic-calmed bicycle boulevard.

Traffic diverters prevent access to both directions of motor vehicle traffic.

General Intersection Design Guidelines

A wide variety of intersection treatments exist, which provide safe crossing and turning movements of bicyclists on bikeways. Treatments specific to particular facility types were previously discussed; this section addresses general guidelines for crossings.

Bicycle Considerations at Traffic Signals

Bicycles typically travel much slower than motor vehicles and can find themselves without an adequate 'clearance interval', which is the time to clear the intersection between conflicting green phases. The duration of the amber phase of signals is typically determined by the expected motor vehicle speed through an intersection. Bicyclist speeds average 10mph through intersections. Methods for accommodating bicyclists include:

- Lengthening the amber phase of the intersection slightly to allow for the slower speed of bicyclists. This should be part of the solution as longer amber phases can also encourage motor vehicles to enter intersections under this phase.
- Lengthening the 'all red' phase of the intersection. This allows any vehicles or bicyclists still in the intersection to clear it before a green phase is given to opposing traffic. The maximum length of the 'all red' phase should not generally be greater than 3 seconds. Under no circumstances should this time be extended beyond 6 seconds.
- Coordinating signals to allow for the 10-15mph propagation speed of bicyclists. Sometimes it is possible to alter signal timing to provide 'green waves' for bicyclists without significantly impeding motor vehicle flow.
- Increase in the minimum green phase. Bicyclists have slower speeds and accelerations than motor vehicles and even if they are at the stop line when a green light is given, the bicyclist may still lack sufficient time to clear the intersection before a conflicting green phase.
- Use signal detection to detect moving bicyclists. Video detection technology can be programmed to detect the presence of bicyclists and alter the minimum green phase, or the clearance interval based on their presence.

Loop Detector Signal Detection for Bicyclists

Design Summary

In order to minimize delay to bicyclists, it is recommended to install one loop about 100 ft from the stop bar within the bike lane, with a second loop located at the stop bar.

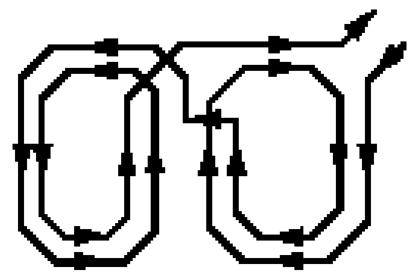
Discussion

The purpose of bicycle loops is to detect bicyclists waiting at intersections, and to give cyclists extra green time (e.g. five seconds) before the light turns yellow to make it through the light.

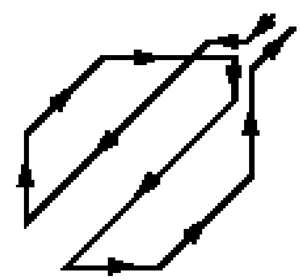
Two loop detector types appropriate for bicycle detection, Type "C" (quadrupole) and Type "D" (diagonal slashed), are shown at right. Details of saw cuts and winding patterns for inductive detector loop types appear on Caltrans Standard Detail ES5B. Loop types B (5' square diamond), C (quadrupole), D (diagonal-slashed), Q and modified Type E (circle with a slash) can reliably detect bicycles across their full width. Type D loop is preferred as it has a good, fairly uniform response to bicycles across its area. Types A (6' square) and E (unmodified circle) are not bike-sensitive in their center. Typically signal detection should be located on secondary cross-streets with intersections to primary roadways where signals are demand activated.

Guidance

2009 MUTCD



Quadrupole Loop – Type "C"
Detects most strongly in center
Sharp cut-off sensitivity
Used in bike lanes



Diagonal Quadrupole Loop – Type "D"
Sensitive over whole area
Sharp cut-off sensitivity
Used in shared lanes

Loop Detector Pavement Markings and Signage

Design Summary

Bicycle-activated loop detectors are installed within the roadway to allow the presence of a bicycle to trigger a change in the traffic signal. This allows the bicyclist to stay within the lane of travel and avoid maneuvering to the side of the road to trigger a push button.

Most demand-actuated signals in Greenville currently use loop detectors, which can be attuned to be sensitive enough to detect any type of metal, including steel and aluminum. Some bicycles may lack enough detectable material by the loop such as models that are mainly composed of carbon fiber or aluminum.

Current and future loops that are sensitive enough to detect bicycles should have pavement markings to instruct cyclists how to trip them, as well as signage (see right).

Discussion

Locate Bicycle Detector Pavement Marking over center of quadrupole loop detector if in bike lane, or where bicycle can be detected in a shared lane by loop detector or other detection technology.

Guidance

2009 MUTCD

AASHTO *Guide for the Development of Bicycle Facilities*

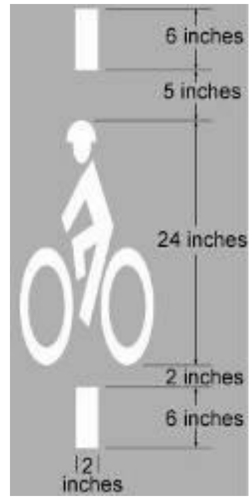


Figure 9C-7 MUTCD

Accompanying Signage (R10-22)

Remote Traffic Microwave Sensor Detection

RTMS is a system developed in China, which uses frequency modulated continuous wave radio signals to detect objects in the roadway. This method is marked with a time code which gives information on how far away the object is. The RTMS system is unaffected by temperature and lighting, which can affect standard video detection cameras.

Bicycle Push Buttons

Design Summary

Bicycle push buttons can also provide signal actuation and timing adjustments for bicyclists. Push buttons are recommended for use with shared-use paths or other unique interactions with bicycle facilities.

Push buttons are generally unsuitable for conventional bike lane situations as the bicyclist would have to leave the roadway to activate the signal. An acceptable situation exists where a push button can be located closer to the bike lane if no vehicle right turn lane is present so that the bicyclist does not have to dismount to reach the signal.

Discussion

- Bicycle push buttons may be used where a push button detector has been installed exclusively to activate a green phase for bicyclists.
- The R10-4, R10-24, R10-25, R10-26 and R62C signs should be installed near the edge of the sidewalk, in the vicinity of where bicyclists will be crossing the street.

Guidance

2009 MUTCD

AASHTO *Guide for the Development of Bicycle Facilities*

2009 MUTCD

Video Detection

Inductive loop detection technology may not always pick up a bicyclist's presence. If the bicyclist fails to position themselves correctly over the loop or is riding a bicycle made of alternative materials such as carbon fiber the detector may not actuate the signal. Video detection technology can detect a bicyclist's presence over a larger area by using pixel analysis of an image to detect the presence of vehicles or bicycles. Changes to the detection can be made quickly with a few modifications to the software to adjust to a change in lane configuration or the addition of a bike lane.

With video detection, disturbance to the pavement, stenciling, and signage can be avoided. Shortcomings can include poor detection in darkness (a lighted intersection solves this), and the shadows of adjacent vehicles triggering the bicycle area during certain times of day.

Video camera system costs range from $20,000 to $25,000 per intersection.

Bicycle Box – Single Lane – No Vehicle Right Turns

Design Summary

Bicycle Box Dimensions:

The Bicycle Box should be 14' deep to allow for bicycle positioning.

Signage:

Appropriate signage as recommended by the MUTCD applies. Signage should be present to prevent 'right turn on red' and to indicate where the motorist must stop.

Discussion

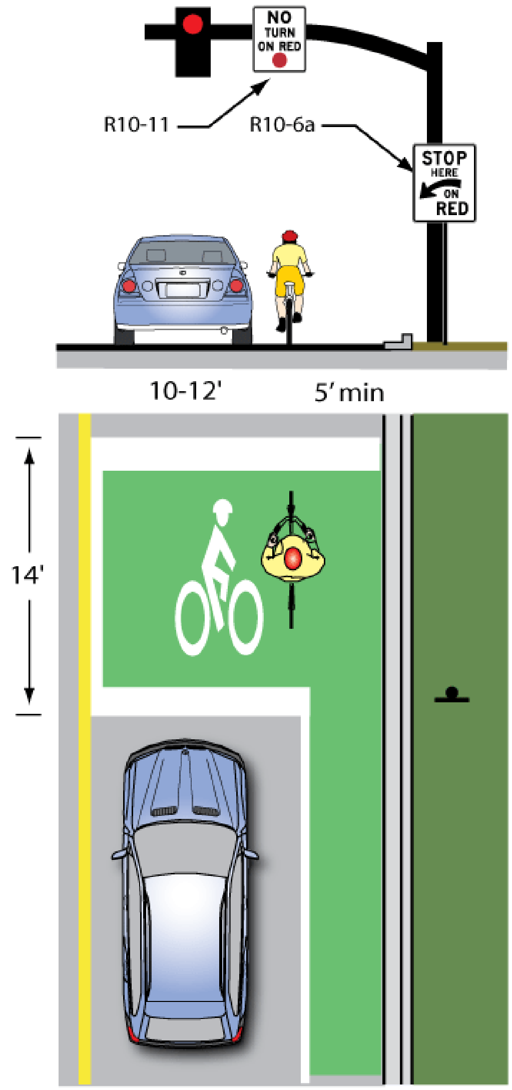
Bicycle boxes provide additional space for bicyclists to move to the front of the vehicular queue while waiting for a green light. On a two-lane roadway, the bicycle box can also facilitate left turning movements for bicyclists as well as through bicycle traffic. Motor vehicles must stop behind the white stop line at the rear of the bicycle box and may not turn right on red.

Guidance

This treatment is not currently present in any U.S. State or Federal design manuals.

NACTO *Urban Bikeway Design Guide*: Bike Boxes

Examples of this treatment can be found in Cambridge, (Mass.) Portland, Austin, and Vancouver.



Bicycle Box – Multi Lane – No Vehicle Right Turns

Design Summary

Bicycle Box Dimensions:

The Bicycle Box should be 14' deep to allow for bicycle positioning.

Signage:

Appropriate signage as recommended by the MUTCD applies. Signage should be present to prevent 'right turn on red' and to indicate where the motorist must stop.

Discussion

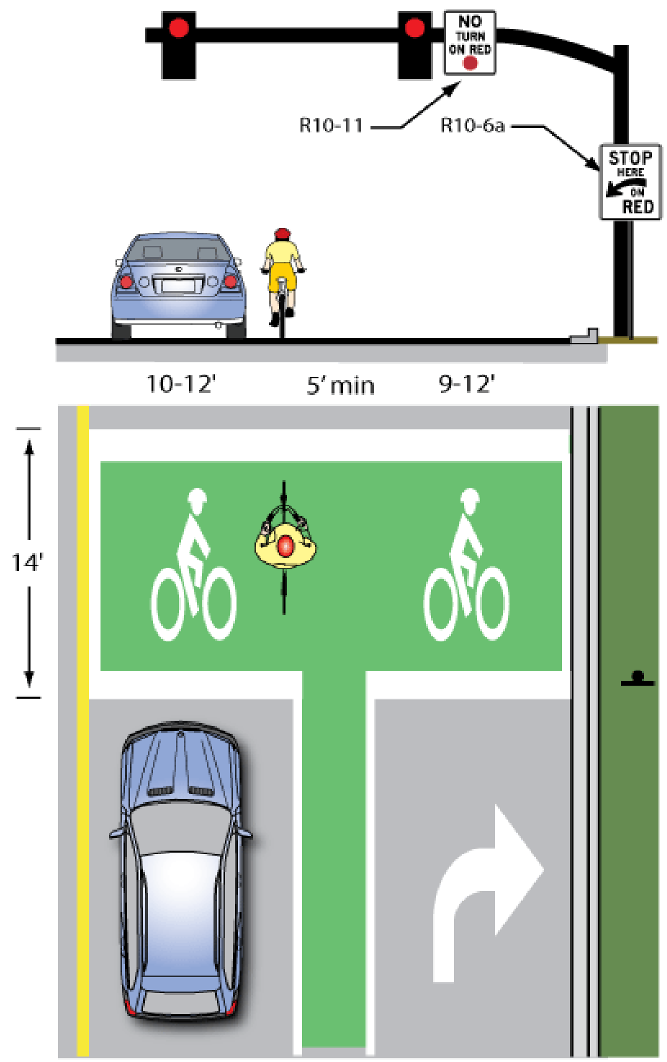
On wider roadways, the Bicycle Box can allow for movements in all directions for bicyclists providing for right turning, through, and left turning movements ahead of traffic. This treatment can be combined with a bicycle signal or an advanced signal phase to clear queuing bicyclists before vehicles are given a green phase.

At multi-lane bicycle boxes there can be a safety issue if a bicyclist is using the bicycle box to maneuver for a left turn just as the signal turns green. This would put the bicyclist possibly in the path of an approaching vehicle. It is recommended that installations wider than one lane across from the access point to the bicycle box be studied carefully before installation.

Guidance

NACTO *Urban Bikeway Design Guide*

This treatment is not currently present in any U.S. State or Federal design manuals.



Bicycle Box – Multi Lane – Right Turns Allowed

Design Summary

Bicycle Box Dimensions:

The Bicycle Box should be 14' deep to allow for bicycle positioning.

Signage:

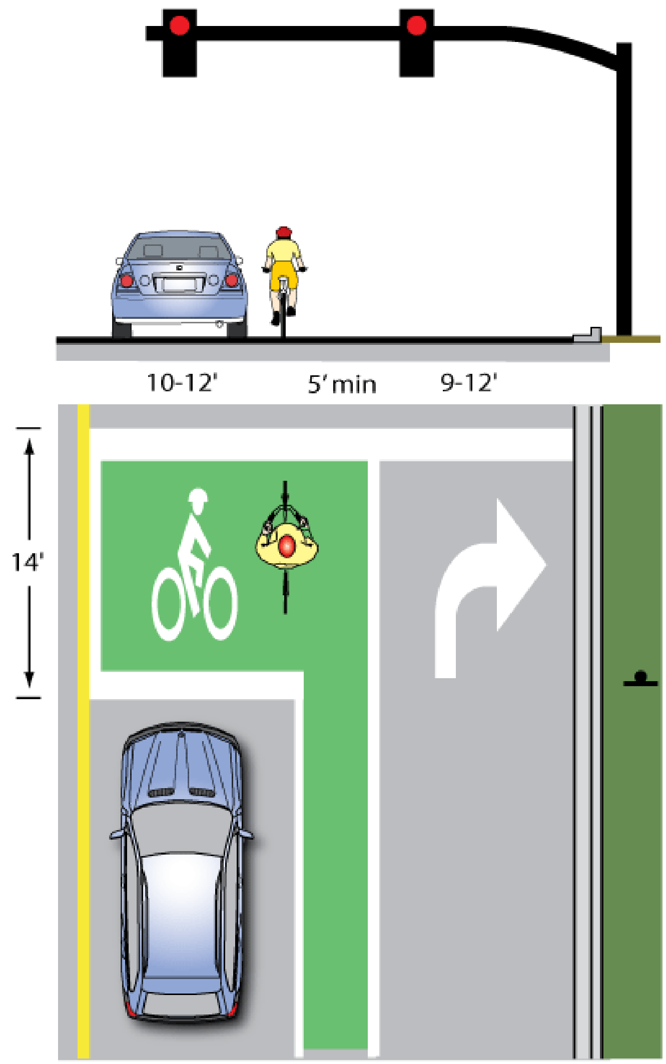
Appropriate signage as recommended by the MUTCD applies.

Discussion

In some areas there may be a situation where a freeway ramp exists where bicycles are prohibited or areas where bicycles may not need to access such as parking garages. In these limited cases a vehicle right turn only lane may be provided to the outside of the bicycle box. Right turns on red are permitted in these instances.

Guidance

This treatment is not currently present in any U.S., State, or Federal design manuals.



Bicycle Parking

Short Term Parking

Design Summary

Location

50' maximum distance from main building entrance.

2' minimum from the curb face to avoid 'dooring.'

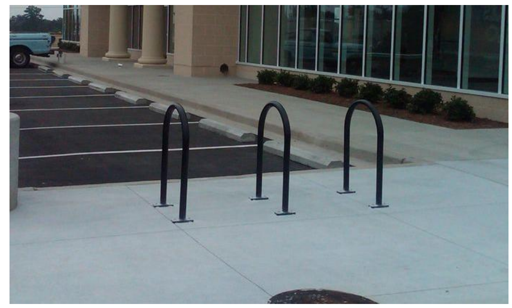
Avoid fire zones, loading zones, bus zones, etc.

Location should be highly visible from adjacent bicycle routes and pedestrian traffic.

Additional Considerations

To allow ample pedestrian movement, a minimum clear distance of 6' should be provided between the bicycle rack and the property line. A clear distance of 5' is the minimum standard.

If two racks are to be installed parallel to each other, a minimum of 3' should be provided between the racks.



Standard bicycle rack

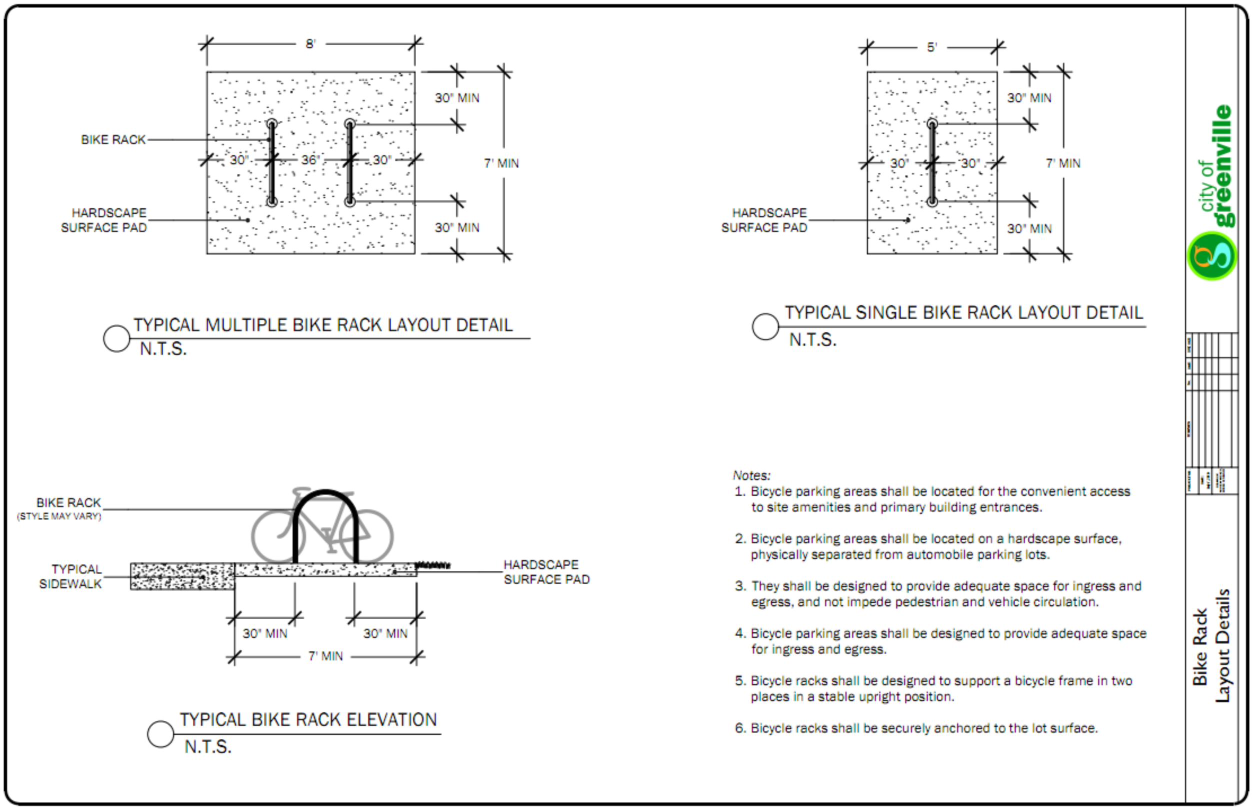
Discussion

Bicycle racks are generally appropriate for commercial and retail areas, office buildings, healthcare and recreational facilities, and institutional developments such as libraries and universities. On-sidewalk racks should be placed adjacent to the curb in the utility strip, where other street furniture, utility poles, and trees are located. Racks should be oriented so that bicycles are positioned parallel to the curb, where neither the rack nor the bicycle in it impedes pedestrian traffic. Where a clear right-of-way for pedestrians cannot be maintained by installing the rack on the sidewalk, place bicycle racks in curb extensions or on-street (see next page). A certain number of bicycle racks should be weather protected. This may be achieved by simply locating the racks under awnings.

Custom racks using creative designs can double as public artwork or advertising space for local businesses. The "post and ring" style rack is an attractive alternative to the standard inverted-U, which requires only a single mounting point and can be customized to have the City's name or emblem stamped into the rings. Where older-style parking meters have been replaced with newer models but have not been removed, it is possible to retrofit them to provide short-term parking. The meter head is removed, and the post remains. A loop may be attached to the pole, in order to accommodate cable locks and to formalize the meter as bicycle parking.

Examples of bike parking signage

Short Term Parking Design Guidance



City of Greenville Bicycle Rack Placement Guidelines

Bike Parking Design Issue	Recommended Guidance
Minimum Rack Height	To increase visibility to pedestrians, racks should have a minimum height of 33 inches or be indicated or cordoned off by visible markers.
Signing	Where bicycle parking areas are not clearly visible to approaching cyclists, signs at least 12 inches square should direct them to the facility. The sign should include the name, phone number, and location of the person in charge of the facility, where applicable.
Lighting	Lighting of not less than one foot-candle illumination at ground level should be provided in all bicycle parking areas.
Frequency of Racks on Streets	In popular retail areas, two or more racks should be installed on each side of each block. This does not eliminate the inclusion of requests from the public which do not fall in these areas. Areas officially designated or used as bicycle routes may warrant the consideration of more racks.
Location and Access	Access to facilities should be convenient; where access is by sidewalk or walkway, ADA-compliant curb ramps should be provided where appropriate. Parking facilities intended for employees should be located near the employee entrance, and those for customers or visitors near main public entrances. (Convenience should be balanced against the need for security if the employee entrance is not in a well-traveled area). Bicycle parking should be clustered in lots not to exceed 16 spaces each. Large expanses of bicycle parking make it easier for thieves to be undetected.
Locations within Buildings	Provide bike racks within 50 feet of the entrance. Where a security guard is present, provide racks behind or within view of a security guard. The location should be outside the normal flow of pedestrian traffic.
Locations near Transit Stops	To prevent bicyclists from locking bikes to bus stop poles - which can create access problems for transit users, particularly those who are disabled - racks should be placed in close proximity to transit stops where there is a demand for short-term bike parking.
Locations within a Campus-Type Setting	Racks are useful in a campus-type setting at locations where the user is likely to spend less than two hours, such as classroom buildings. Racks should be located near the entrance to each building. Where racks are clustered in a single location, they should be surrounded by a fence and watched by an attendant. The attendant can often share this duty with other duties to reduce or eliminate the cost of labor being applied to bike parking duties; a cheaper alternative to an attendant may be to site the fenced bicycle compound in a highly visible location on the campus. For long-term parking needs of employees and students, attendant parking and/or bike lockers are recommended.
Retrofit Program	In established locations, such as schools, employment centers, and shopping centers, the City should conduct bicycle audits to assess bicycle parking availability and access, and add additional bicycle racks where necessary.

On-Street Corrals

Design Summary

- See guidelines for sidewalk bicycle rack placement and clear zones.
- Can be used with parallel or angled parking.
- Each motor vehicle parking space can be replaced with approximately 6-10 bicycle parking spaces.
- Protect bicycles from motor vehicles with physical barriers such as curbs, bollards, or fences or through the application of other unique surface treatments.
- Establish maintenance responsibility when facility is built, particularly street sweeping and snow removal.
- Parking stalls adjacent to curb extensions are good candidates for bicycle corrals since the concrete extension serves as delimitation on one side.
- Cyclists should be able to access the corral from both the sidewalk and the roadway.
- Cyclists should have an entrance width from roadway of 5 – 6'.

On-street bicycle parking may be installed at intersection corners or at mid-block locations.

Discussion

Bicycle corrals (also known as "in-street" bicycle parking) consist of bicycle racks grouped together in a common area within the public right-of-way traditionally used for automobile parking. Bicycle corrals are reserved exclusively for bicycle parking and provide a relatively inexpensive solution to providing high-volume bicycle parking. Bicycle corrals can be implemented by converting one or two on-street motor vehicle parking spaces into on-street bicycle parking.

Bicycle corrals move bicycles off the sidewalks, leaving more space for pedestrians, sidewalk café tables, etc. Because bicycle parking does not block sightlines (as large motor vehicles would do), it may be possible to locate bicycle parking in 'no-parking' zones near intersections and crosswalks.

Bicycle corrals can be considered instead of other on-street bicycle parking facilities where:

- High pedestrian activity results in limited space for providing bicycle racks on sidewalks.
- There is a moderate to high demand for short-term bicycle parking.
- Sufficient on-street vehicular parking is provided
- The business community is interested in sponsoring the bicycle corral.

In many communities, including Portland, the installation of bicycle corrals is driven by requests from adjacent businesses, and is not a city-driven initiative. In such cases, the City does not remove motor vehicle parking unless it is explicitly requested. In other areas, the City provides the facility and business associations take responsibility for the maintenance of the facility. Many communities, including the City of Portland, establish maintenance agreements with the requesting business.

The bicycle corral can be visually enhanced through the use of attractive planters and vegetation to act as buffers from the motor vehicle parking area as well as the use of creative demarcation elements to separate the corral for motor vehicle traffic.

Shelters

Design Summary

See guidelines for sidewalk bicycle rack placement and clear zones.

To be located on-street or off-street, in areas of high potential demand, such as areas in close proximity to major employment areas, schools, or community and recreational facilities.

Recommended height: 8-12'

Roof area: 12-15'.

If the bicycle racks are located perpendicular to a wall, 2' minimum clearance (single-side access); and 2.5 m (double-sided access).

If the bicycle rack is located parallel to a wall, 8' minimum clearance should be provided.

A clear width of 3' should be provided between rack ends to balance the maximization of bicycle parking capacity with the need for adequate bicycle maneuverability.

Bicycle parking shelter on a sidewalk in downtown Victoria, Canada.

Discussion

Bicycle shelters consist of bicycle racks grouped together within structures with a roof that provides weather protection. Bicycle shelters provide convenient short-term and long-term bicycle parking. They also offer extra protection against accidental damages by providing greater separation between the bicycles and the sidewalk or parking lane. Information boards and advertising space can also be incorporated onto the bicycle shelter which is often used to post cycling or bicycle related information. Bicycle shelters provide a high level of aesthetic adaptation as each of its components (shelter, racks, roof) may be enhanced with different shapes, colors and materials.

Bicycle shelters are warranted anywhere that bicycle racks may be located, particularly:

Major commercial and retail areas, particularly in the major commercial nodes.

Areas with sufficient space on sidewalks, promenades or public plazas, or curb extensions, so that adequate sidewalk width can be maintained.

Demand for bicycle parking is oriented more towards long-term parking.

The location chosen for the bicycle shelter should be central to all surrounding activities so cyclists can park and walk conveniently to their final destination.

Bicycle parking area signage should be provide to indicate to cyclists and pedestrians that the bicycle shelter is intended exclusively for bicycle use and to alert pedestrians and motorists that they can expect higher bicycle volumes in the area.

Long-Term Parking

Long-term facilities protect the entire bicycle, its components and accessories against theft and against inclement weather, including snow and wind-driven rain. Long-term parking facilities are more expensive to provide than short-term facilities, but are also significantly more secure. Potential locations for long-term bicycle parking include transit stations, large employers and institutions where people use their bikes for commuting, and not consistently throughout the day.

Bike Lockers

Design Summary

- Place in close proximity to building entrances or transit exchanges, or on the first level of a parking garage.
- Provide door locking mechanisms and systems.
- A flat, level site is needed; concrete surfaces preferred.
- Enclosure must be rigid.
- Transparent panels are available on some models to allow surveillance of locker contents.
- Integrated solar panels have been added to certain models for recharging electric bicycles.
- Minimum dimensions: width (opening) 2.5'; height 6'; depth 4'.
- Stackable models can double bicycle parking capacity.

A bike locker at an office building (shown in 'open' position).

Discussion

Although bicycle lockers may be more expensive to install, they can make the difference for commuters who are deciding whether or not to cycle. Bicycle lockers are large metal or plastic stand-alone boxes and offer the highest level of bicycle parking security available.

Some lockers allow access to two users - a partition separating the two bicycles can help ensure users feel their bike is secure. Lockers can also be stacked, reducing the footprint of the area, although that makes them more difficult to use.

Security requirements may require that locker contents be visible, introducing a tradeoff between security and perceived safety. Though these measures are designed to increase station security, bicyclists may perceive the contents of their locker to be less safe if they are visible and will be more reluctant to use them. Providing visibility into the locker also reduces unintended uses, such as use as homeless shelters, trash receptacles, or storage areas. Requiring that users procure a key or code to use the locker also reduces these unintended uses.

Traditionally, bicycle lockers have been available on a sign-up basis, whereby cyclists are given a key or a code to access a particular locker. Computerized on-demand systems allow users to check for available lockers or sign up online. Models from eLocker and CycleSafe allow keyless access to the locker with the use of a SmartCard or cell phone. With an internet connection, centralized computerized administration allows the transit agency to monitor and respond to demand for one-time use as well as reserved lockers.

Lockers available for one-time use have the advantage of serving multiple users a week. Monthly rentals, by contrast, ensure renters that their own personal locker will always be available. Bicycle lockers are most appropriate:

- Where demand is generally oriented towards long-term parking.
- At transit exchanges and park-and-rides to help encourage multi-modal travel.
- Medium-high density employment and commercial areas and universities.
- Where additional security is required and other forms of covered storage are not possible.

Bicycle Compounds/Cages

Design Summary

See guidelines for bicycle rack placement and clear zones.

A cage of 18' by 18' can accommodate up to 20 bicycles and uses the space of approximately two automobile parking spots.

Improve surveillance through public lighting and video cameras.

Bicycle compounds shall have an exterior structure consisting of expanded metal mesh from floor to ceiling.

In an attended parking facility, locate within 100' of an attendant or security guard or must be visible by other users of the parking facility.

Entry doors must be steel and at least 2.5' in width, with "tamper proof" hinges. A window may be provided in the door to provide permanent visual access.

Accommodate a maximum of 40 bicycles or 120 if the room is compartmentalized with expanded metal mesh with lockable industrial-grade doors into enclosures containing a maximum of 40 bicycles.

This bike cage in Penn Station, New York City provides wave racks and uses a passcard for access.

Secure Parking Area (SPA) in Portland, OR use both inverted 'u' racks (right) and racks that stack bicycles.

Discussion

Bicycle compounds are fully enclosed, stand-alone bicycle parking structures. Compounds should not only have a locked gate but should also allow for the frame and both wheels to be locked to a rail, as other users also have access to the enclosure. Bicycle compounds are recommended for employment or residential bicycle parking areas, or for all-day parking at transit exchanges, workplaces and schools. They can be located at street level or in parking garages.

Bicycle Secure Parking Areas (SPAs) are a new concept implemented for TriMet (Portland, Oregon's transit agency). They provide high capacity, secure parking areas for 80-100 bicycles at light rail and bus transit centers. The Bicycle SPAs are semi-enclosed covered areas that are accessed by key cards and monitored by security cameras. The increased security measures provide an additional transportation option for those who may not be comfortable leaving their bicycle in an outdoor transit station exposed to weather and the threats of vandalism. They also include amenities that make the Bicycle SPA more attractive and inviting for users such as benches, bicycle repair stations, bicycle tube and maintenance item vending machines, as well as hitching posts which allow people to leave their locks at the SPA.

Bicycle Rooms

Design Summary

- See guidelines for bicycle rack placement and clear zones.
- Improve surveillance through public lighting and video cameras.
- Walls should be solid and opaque from floor to ceiling.
- Install a panic button so as to provide a direct line of security in the event of an emergency.
- Accommodate a maximum of 40 bicycles or 120 if the room is compartmentalized with expanded metal mesh with lockable industrial-grade doors into enclosures containing a maximum of 40 bicycles.

Bike rooms can be provided in office or apartment buildings.

Discussion

Bicycle rooms are locked rooms or cages which are accessible only to cyclists, and which may contain bicycle racks to provide extra security against theft. Bicycle rooms are used where there is a moderate to high demand for parking, and where cyclist who would use the bicycle parking are from a defined group, such as a group of employees. Bicycle rooms are also popular for apartment buildings, particularly smaller ones in which residents are familiar with one another.

The bicycle parking facilities shall be no further from the elevators or entrances than the closest motor vehicle parking space, and no more than 150' from an elevator or building entrance. Buildings with more than one entrance should consider providing bicycle parking close to each entrance, and particularly near entrances that are accessible through the bicycle network. Whenever possible, bicycle parking facilities should allow 24-hour secure access.

Dedicated bicycle-only secure access points shall be provided through the use of security cards, non-duplicable keys, or passcode access. The downside is that bicyclists must have a key or know a code prior to using the parking facilities, which is a barrier to incidental use.